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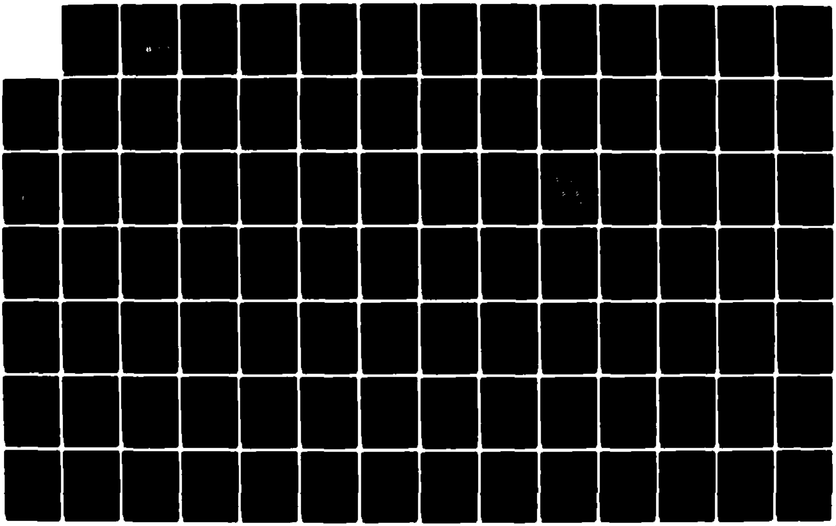

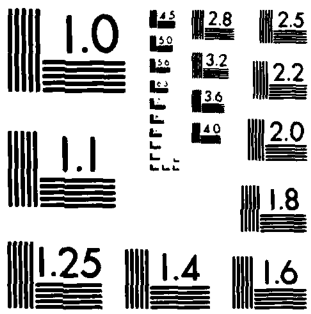
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LARGE SCREEN DISPLAY TECHNOLOGY SURVEY

By
RICHARD M. CARBONE

JULY 1984

Prepared for

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This document provides information on the technologies of large screen displays which can be used in command and control applications. The present survey incorporates information on existing product line equipment and includes new devices which are just entering the market or are in an advanced stage of development. This material is based upon the results of an extensive survey of manufacturers of large screen display equipment for commercial and military applications.

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11. TECHNOLOGY SURVEY

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EXECUTIVE SUMMARY

This document provides information on the technologies of large screen displays which can be used in command and control applications.

The present survey incorporates information on existing product line equipment and includes new devices which are just entering the market or are in an advanced stage of development. This material is based upon the results of an extensive survey of manufacturers of large screen display equipment for commercial and military applications.

Since the publication of the referenced report, several of the vendors have developed improvements or refinements in their product line. Some have changed their basic design of large screen displays, and some companies have ventured into the marketplace. There is a trend in the field toward the use of multiple projectors to produce color images. With the exception of the General Electric large screen display, all large display systems surveyed use multiple projectors for color production.

Due to the high cost of these units, the market for large screen displays is limited to a small select group of users. Most of the systems are utilized by military command and control centers for the presentation of defense or tactical information.

Gretag/Eidophor has replaced their monochrome Model EP-8-SQ with a new monochrome display, the Model 5180, which has a high luminous output.

General Dynamics has concentrated on a multiple (two and three projector) configuration for four-color and full-color presentations.

General Electric has added a new high-intensity projector, the PJ 5155, based upon its standard Schlieren optics design.

Aeronutronic Ford continues to market the ATP-1000, the ATP-3000 (Three-Pack) and the ATP-6000 (Six-Pack).

Hughes has developed four-color and full-color liquid crystal projectors based on the use of multiple projectors.

Singer/Librascope has developed a laser-addressed liquid crystal display to replace their laser-addressed film-scriber system.

Litton Industries light emitting diode (LED) matrix display has undergone minor development in its module construction production techniques.

Kalart-Victor continues to market its developed product line, which is basically unchanged.

Three new companies have entered the large screen display field: Sodern/Titus ("Sodern Visualization System"), Electronic Systems Products, Inc. ("Aquastar"), and Videpro International Products Limited ("Hi-Beam"). The Sodern/Titus solid-state light valve is a newly-developed product produced by Sodern of Limeil-Brevannes, France. A prototype unit has been demonstrated and Sodern is presently building two full-color prototypes. This unit provides good resolution and more luminance than is attainable with competitive products. The first prototype system was constructed for the Danish Navy and was completed in 1982; the second system was built for the French Military Administration. The "Aquastar" and "Hi-Beam" units employ multiple CRT projection systems offering full-color displays with moderate resolution and luminous output in low-cost products.

Regarding large screen display components, four new products are currently being researched and developed. They include a new high-efficiency rear projection display screen, thermal and light-activated magneto-optic displays and a matrix flat-panel display. The magneto-optic devices, because of their solid-state design, are particularly suited to military and industrial applications. Their inherent low power, reliability, ruggedness and potential low production cost make them ideal for military applications. The "Flatscreen" matrix technology uses a high degree of multiplexing within the panel device, which should result in a substantial savings in the cost of electronics when compared to other flat-panel matrix or plasma devices.

Acquisition costs, for similar 1979/1983 products, have increased approximately with the inflation rate. No consistent trend is noted with regard to operating cost.

The majority of the values of resolution stated in 1979 remain essentially the same today; the brightness output has also remained relatively constant. Several manufacturers, such as General Electric and General Dynamics, have developed high-intensity

versions of their product line units: the General Electric PJ 5155 and the General Dynamics 303F.

The vendors and the display products in this survey are discussed in Appendices A and B.

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SECTION I

INTRODUCTION

This volume examines new equipment and cost changes, improvements to existing equipment, and new technological advances in the large screen display field since 1979.

Contacts with vendors referred to in the 1979 survey revealed that some have discontinued their large screen product line, and several additional vendors have entered the market. In addition, there have been new developments in display components, which may be applicable to large screen display systems. In most cases, a visit was made to the manufacturer's facility to view the equipment under discussion.

The Advent Corporation has been purchased by Projectron, Inc. of Lexington, Kentucky and will market a new line of large screen display products.

The vendors who were not addressed in the initial survey, but appear in this report are: Aydin Control, Electronics Systems Products, Videpro International, Lucitron, Inc., Philips of Hamburg, Germany and Photonics Technology.

Litton Industries and Philips of Hamburg, Germany are independently developing new components which can be employed as a projection device in large screen displays based on magneto-optic principles. The benefits of these new devices are their ability to be fabricated by Very Large Scale Integration (VLSI) processes, therefore providing the potential of a low-cost light valve for large screen displays. These new devices utilize an optical phenomenon based upon the Faraday Effect, in which elements become optically active when subjected to a strong magnetic field.

Lucitron, Inc. has developed a new gas-electron-phosphor display which appears very promising. The "Flatscreen" technique uses a unique method of address mutiplexing to access areas on the display resulting in a possible substantial savings in the cost of associated electronics. This product appears to have the potential for a low cost large screen display.

Magnavox Government and Industrial Electronics Company and Photonics Technology Inc. have jointly developed a large one-meter diagonal flat plasma display.

A new screen material has been developed by Freen Screen Manufacturing, Inc. (currently in receivership)[1] for rear projection display systems which provides high gain without limiting viewing angles. An additional feature of this product is its ability to be used in high ambient light conditions.

Section 2 describes technologies employed in current large screen display systems. These technologies are categorized as: 1) direct projection cathode ray tube systems, both transmissive and reflective, 2) light valves: reflective oil film, transmissive oil film liquid crystal, and solid state, and 3) light emitting diodes.

Section 3 addresses current technologies under development which have potential application in large screen display systems. Described in this section are the Freen Screen, two magneto-optics-based prototype systems (Litton Industries and Philips Research Laboratories), a new flat-panel concept called gas-electron-phosphor (Lucitron, Inc.), and a new construction technique for large AC plasma displays (Photonics Technology).

Section 4 describes the performance parameters of the products surveyed together with cost comparisons for delivered performance.

Appendix A contains a compilation of large screen display characteristics including a detailed summary of the specifics for the Large Screen Displays Survey, together with purchase price information, consumables, and operating cost per hour.

Appendix B contains a list of the dynamic characteristics of each large screen display described.

Appendix C contains a discussion on the characteristics of projection screens and details rear projection screens.

Appendix D contains the results of a comparison of a Freen Mark XII Rear Projection Screen and a Standard Rear Projection Unity Gain Screen.

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[1] Reorganized as Phoenix Communications of Baltimore, MD.

SECTION 2

AVAILABLE TECHNOLOGIES FOR LARGE SCREEN DISPLAYS

There are a number of technologies applicable to large screen displays systems including: projection cathode ray tube optical systems; projection light valves, deformable, liquid crystal and solid-state; direct view flat-panel devices; LED, plasma and gas-electron-phosphor.

Direct projection cathode ray tube systems generate an image on the phosphor of a CRT with an electron beam. Image quality and brightness is a direct function of the specific approach taken by the manufacturer. At the low end of the spectrum are projection systems using a single (525 line) monochrome or color shadow mask CRT in conjunction with a projection lens with lens speeds ranging between f/1.0 and f/2.0. At the high end of the spectrum are projection systems which use single or multiple high-brightness and high-resolution (~ 1000 line) CRTs, each with its optical system in the f/0.55 to f/0.70 range (a lower f-number indicates greater brightness in the displayed image). Light emitted by the phosphor is gathered by the optics of the system and focused onto a projection screen via a lens.

Reflective systems (catoptric) locate the face-plate of the CRT at the focal point of a spherical front surface coated mirror, and the reflected image is transmitted through a corrector plate or catadioptric lens (Schmidt optical techniques) and focused onto the display screen (Figures 1 and 2). Transmissive systems (dioptric) locate the face-plate of the CRT at the entrance pupil of a fast, wide angle projection lens and the image is focused onto the display screen (Figure 3).

Color images in large screen displays are accomplished using direct projection CRTs, by the mixing, or superposition, of images from separate projectors on the display screen or by optical mixing at the projection lens.

Increased image brightness is achieved by using a high-brightness version of the conventional shadow mask CRT; by using multiple projectors, or by special purpose (sapphire face) CRTs. Typical off-the-shelf direct projection CRT systems yield a resolution of about 525 TV lines with brightness levels in the order

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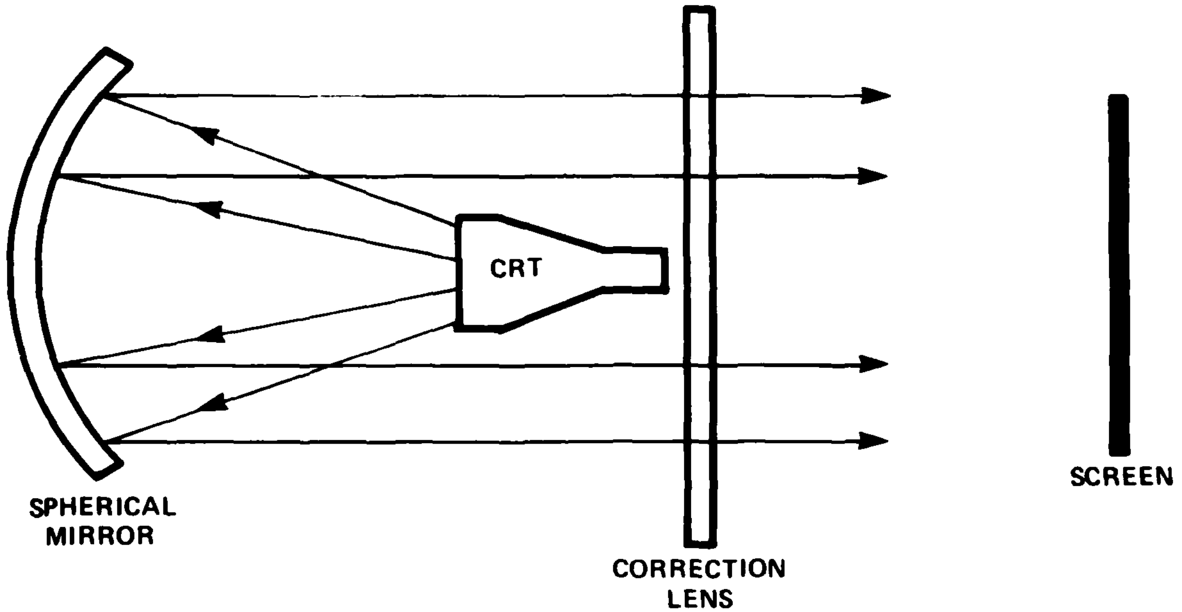


Figure 1. SCHMIDT PROJECTION CRT SYSTEM

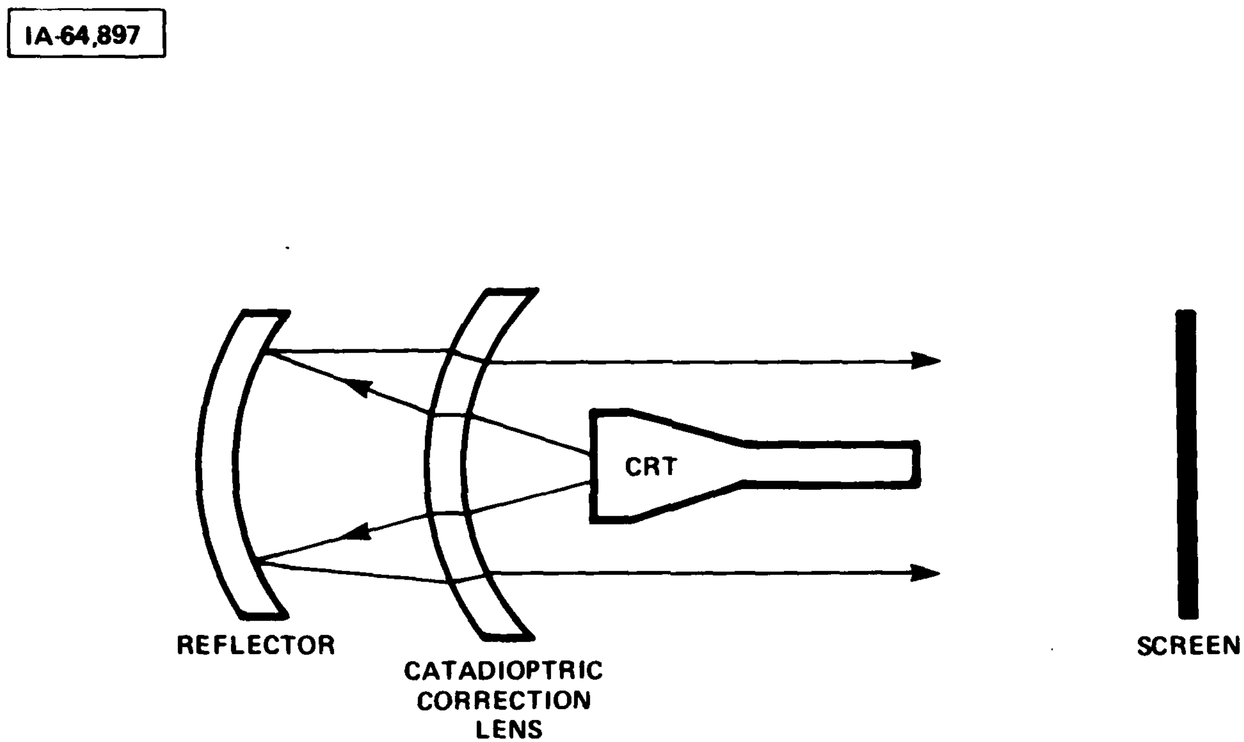


Figure 2. CATADIOPTRIC REFLECTIVE PROJECTION CRT SYSTEM

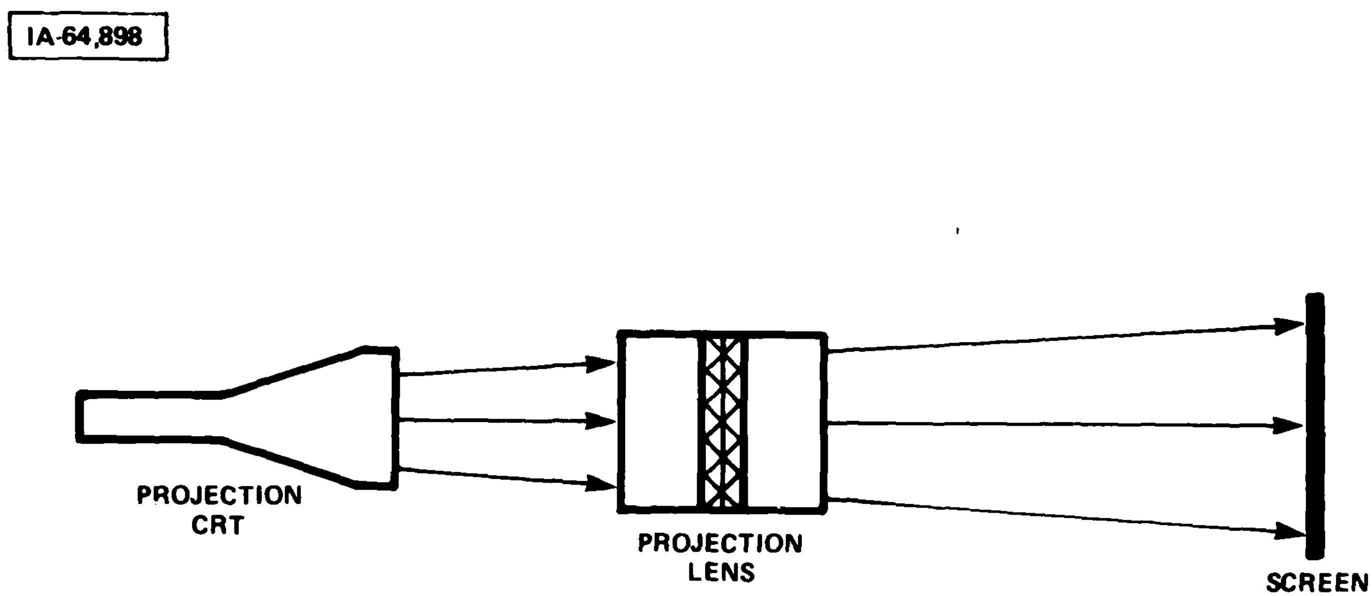


Figure 3. REFRACTIVE PROJECTION CRT SYSTEM

of 300-400 lumens, while high performance display systems deliver 1000 TV lines or more with a brightness level in the order of 1000 lumens.

Acquisition costs for direct image large screen display systems range from $6000 to $1,000,000 or more. A detailed summary of individual equipment costs and characteristics is contained in Tables I, II, and III. Life expectancy for individual CRT's range from 1500 to 2500 hours (recommended replacement at half brightness). A detailed explanation of each vendor's recommended replacement time is provided in Appendices A and B.

"Light valve" is a generic expression which implies switching or modulation of a light beam. In display terminology, "light valve" designates a class of display devices which incorporate an independent light source and a control medium to transform an electrical charge-image to an equivalent optical-image. The control medium performs as an active optical element. By employing the appropriate optical system, an optical image is produced which can be magnified and displayed on a viewing screen.

Light valve display systems employ deformable, liquid crystal, and solid-state approaches. Deformable light valve display systems use a pliant, illuminated fluid-medium addressed by an electron beam using one of two versions of modified Schlieren optics to produce an image on a display screen. Due to the configuration of the modified Schlieren optical system, deformable light valves using this technique can only be addressed in the raster scan mode. A random plot addressing scheme (plotting in x and y) cannot be used because of the slotted mirror imaging optics configuration of this system.

A simple Schlieren optical system is illustrated in Figure 4a. It consists of an entrance and exit bar grating with a Schlieren lens inserted between the two, a projection lens, and a display screen. Each of the bar gratings is placed at the foci of the Schlieren lens and is positioned so that each bar is imaged upon an opening of the second grating. Light rays from an external source, which are made incident upon this combination, are blocked at the f_1 focal plane. By inserting an optical scattering device (a small prism or a comparable refracting medium) between the Schlieren lens and the focal plane f_1, some of the optical rays are refracted by the scattering device and bypass the f_1 plane. The scattered light energy is collected by a projection lens and projected onto a display screen.

This principle is used in the design of a light valve by replacing the scattering device with a transparent oil-film layer and an electron beam (Figure 4b).

TABLE I

LOW-COST LARGE SCREEN DISPLAY SYSTEMS

Vendor/Equipment	Image Mechanism	Contrast Ratio	Luminance (Lumens)	Resolution (TV Lines)	Character Format	Acquisition Cost	Operating Cost/Hour
ELECTRONIC SYSTEMS PRODUCT, INC. Acquastar III B, Full Color	Direct Image	30:1	400	600	Raster Scan	$10,000	$1 to $2
VIDEPRO INTERNATIONAL PRODUCTS Hi-Beam, Full Color	Direct Image	40:1	350	525	Raster Scan	$16,000	$1 to $2
KALART-VICTOR CORP. Telebeam, Monochrome	Direct Image	50:1	350	525	Raster Scan	$6,000	$2

TABLE II

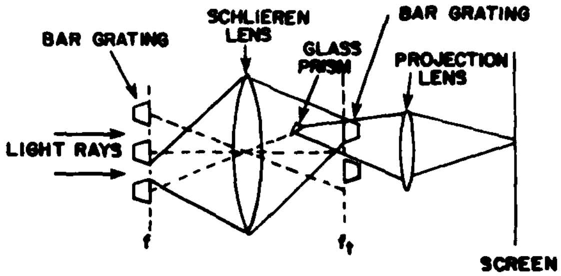
MODERATE-COST LARGE SCREEN DISPLAY SYSTEMS

Vendor/Equipment	Image Mechanism	Contrast Ratio	Luminance (Lumens)	Resolution (TV Lines)	Character Format	Acquisition Cost	Operating Cost/Hour
AYDIN CONTROLS							
8063, Monochrome	Direct Image	5:1	300	1000	Raster Scan	$45,000	$2
8063-C, Four-Color	Direct Image	5:1	300	1000	or	$85,000	$4
8063-A, Full-Color	Direct Image	5:1	300	1000	Random Plot	$120,000	$6
GENERAL ELECTRIC CO.							
PJ 7000, Monochrome	Oil Film Light Valve	75:1	750	1000	Raster	$55,500	$6
PJ 5050, Four-Color	Oil Film Light Valve	75:1	550	1000	Scan	$72,500	$4
PJ5155, Full-Color	Oil Film Light Valve	75:1	1300	1000		$82,000	$6
GENERAL ATRONICS CORP. (Magnavox) SVS12 Sodern/Titus Full Color	Titus Solid State	100:1	1500-1900	525 and 625	Raster Scan	$250,000	$6 to $10

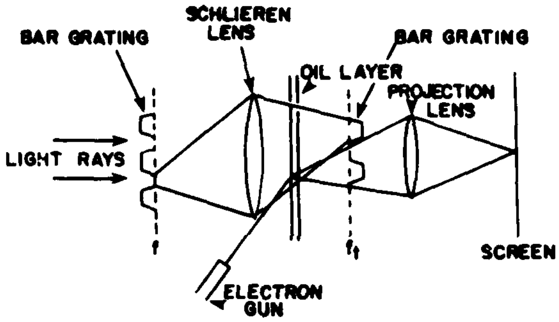
TABLE III

HIGH-COST LARGE SCREEN DISPLAY SYSTEMS

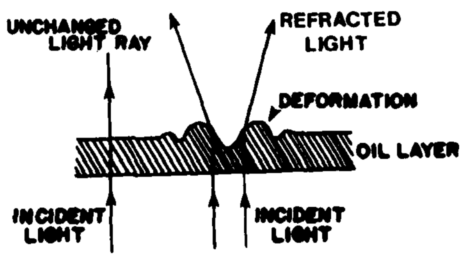
Vendor/Equipment	Image Mechanism	Contrast Ratio	Luminance (Lumens)	Resolution (TV Lines)	Character Format	Acquisition Cost	Operating Cost/Hour
LEAR SIEGLER, INC. GRETAG/EIDOPHOR							
5170, Full-Color	Oil Film Light Valve	100:1	3600	800	Raster Scan	$450,000	$22
5171, Full-Color	Oil Film Light Valve	100:1	7000	800		$505,000	$46
5180, Monochrome	Oil Film Light Valve	100:1	7000	800		$190,000	$7
FORD AEROSPACE							
ATP 1000, Monochrome	Direct Image	15:1	280	1000	Raster Scan	$150,000	$3
ATP 3000, Full-Color	Direct Image	15:1	300	1000		$500,000	$10
ATP 6000, Full-Color	Direct Image	15:1	1200	1000		$1,000,000	$90
GENERAL DYNAMICS							
303B, Monochrome	Direct Image	80:1	560	1000	Raster Scan or Random Plot	$60,000	$2
303C, Four-Color	Direct Image	80:1	1000	1000		$120,000	$4
303F, Full-Color	Direct Image	80:1	1200	1000		$300,000	$6
HUGHES AIRCRAFT CORP.							
HDP 4000, Four-Color	Liquid Crystal Light Valve	20:1 (Yellow)	500	1024 Lines in 1075 - Line Raster	Raster Scan	$400,000	$9
LITTON INDUSTRIES							
Tactical Map, Three-Color	Light Emitting Diode	3.5:1	225	(22 Pixels/In.)	Matrix Addressed	$25,000	$2
SINGER							
Model SL2448	Liquid Crystal Light Valve	50:1	800-1000	2000	Raster Scan or Random Plot	$300,000	$7



SIMPLE SCHLIEREN OPTICAL SYSTEM (a)



SIMPLE OIL-FILM LIGHT VALVE (b)



REFRACTION OF LIGHT BY OIL CONTROL LAYER (c)

Figure 4. SCHLIEREN OIL FILM LIGHT VALVE

With no electron beam impinging upon the oil layer, the light rays are blocked by the Schlieren optical system at the f_1 focal point. When introducing an electron beam aimed at a spot on the oil-control layer, the resulting electrostatic forces cause a ripple on the oil layer (Figure 4c). This perturbation serves as a refracting element, similar to the optical scattering device in the simple Schlieren system, and light rays are refracted in the same manner. The electron beam is modulated to vary the slope of the perturbation which controls the light intensity and therefore the resulting optical image.

Two approaches are used in the modified Schlieren optics, either transmissive or reflective. In the transmissive version (Figure 5), grating-like grooves are formed on the deformable oil surface by electrostatic forces. These forces come from the charge deposited by the scanning electron beam which is modulated by video information. These grating-like groove patterns are made visible by the Schlieren optical system, consisting of a set of input slots and output bars. The resulting raster scanned image is displayed on a screen using a projection lens.

The reflective version (Figure 6) works on the same general principle as the transmissive model, except that the fluid-medium is coated on a spherical mirror and the input slots are actually mirrors located on the output bars.

The liquid crystal light valve employs two approaches to display images. One approach uses a light-activated liquid crystal (Figure 7); the other, a thermo-activated light crystal (Figure 8).

The light activated liquid crystal light valve is based on a principle of physics in crystals called the "twisted-nematic effect". A detailed discussion of this subject is given in Reference 3, "Applied Optics and Optical Engineering". A brief description of the phenomenon is given here: The liquid crystal light-activated light valve is based on the "off-state" and the "on-state" properties of liquid crystals. In the "off-state" the liquid crystal light valve (LCLV) imposes a linear polarization on the transmitted light emerging from the LCLV, and the light is blocked (not transmitted) by a crossed-analyzer placed between the light valve and the illumination source. Therefore, no light is transmitted. In the "on-state", the emerging light from the light valve is elliptically polarized and light in the plane of the analyzer is allowed to pass through the crystal and is transmitted.

The thermo-activated liquid crystal light valve is founded on another principle of physics in crystals called the "smectic-effect". A detailed explanation is given in "Applied Optics and Optical

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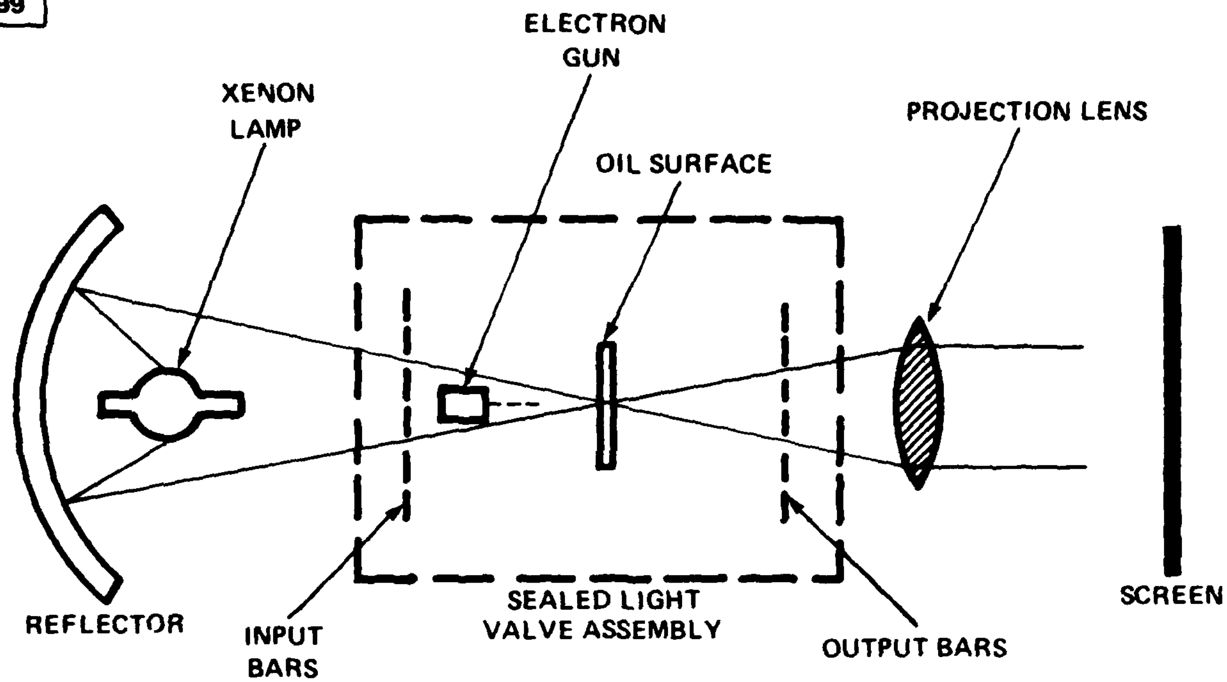

Figure 5. OIL-FILM TRANSMISSIVE LIGHT VALVE

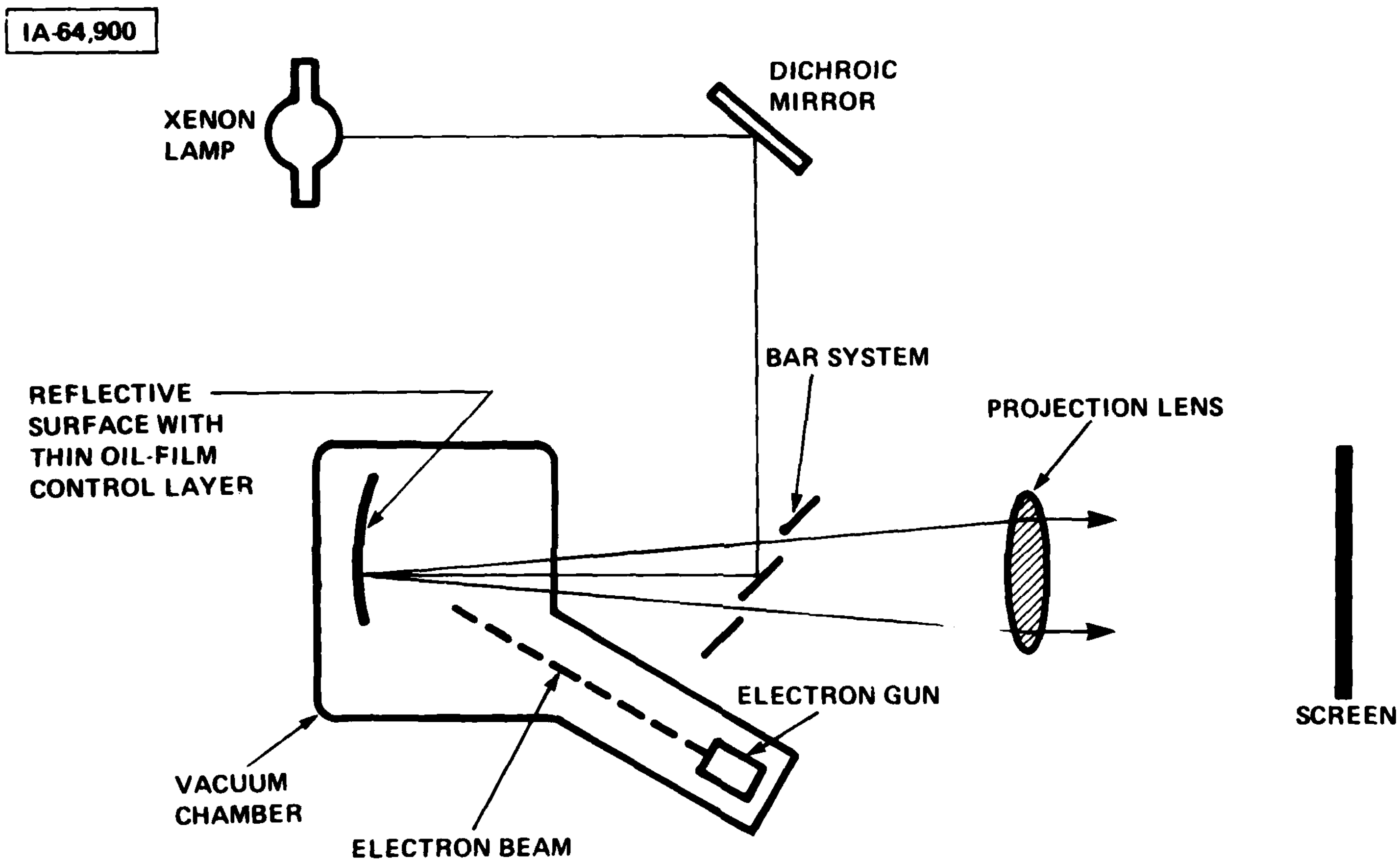

Figure 6. OIL-FILM REFLECTIVE LIGHT VALVE

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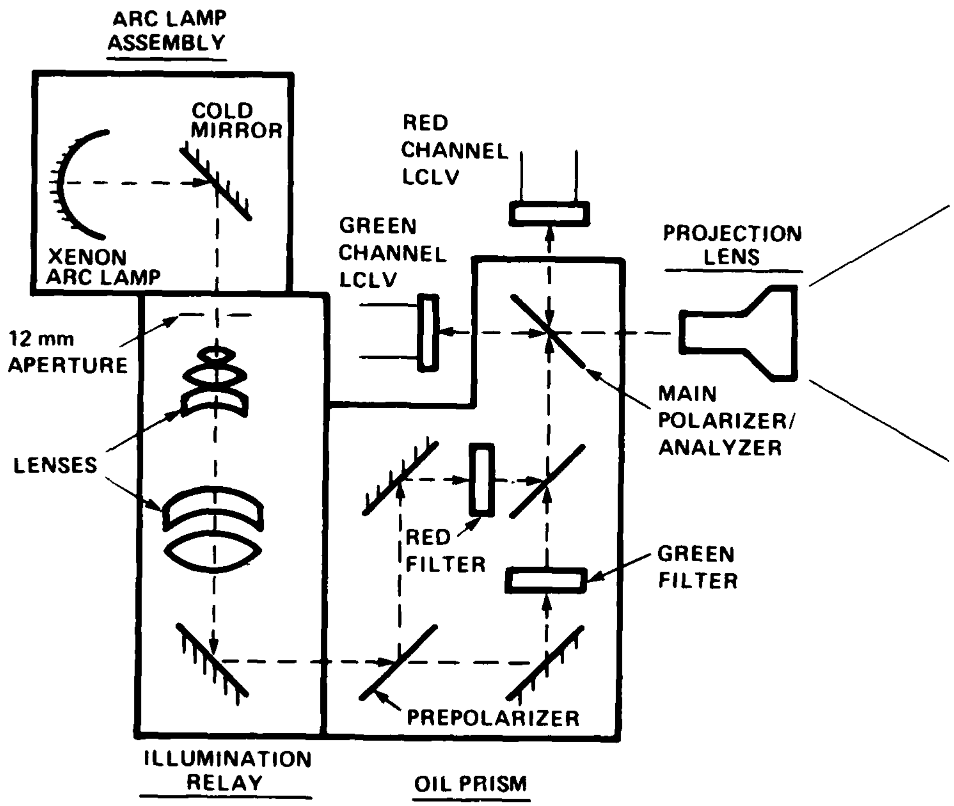

Figure 7. LIGHT ACTIVATED LIQUID CRYSTAL LIGHT VALVE OPTICAL SYSTEM

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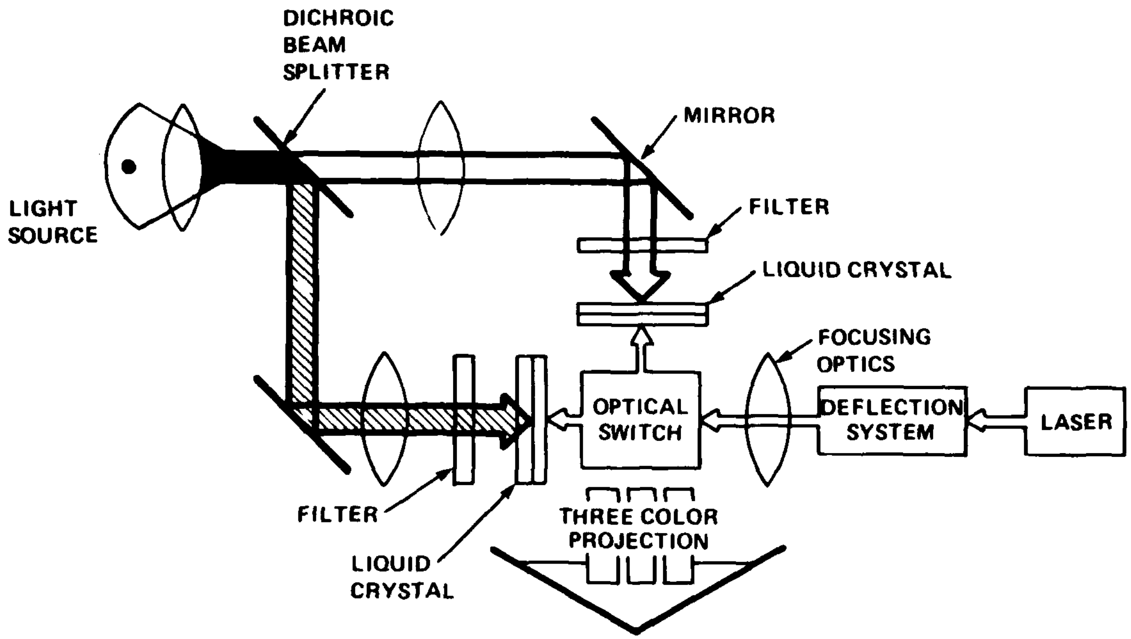


Figure 8. THERMO-ACTIVATED LIQUID CRYSTAL LIGHT VALVE OPTICAL SYSTEM

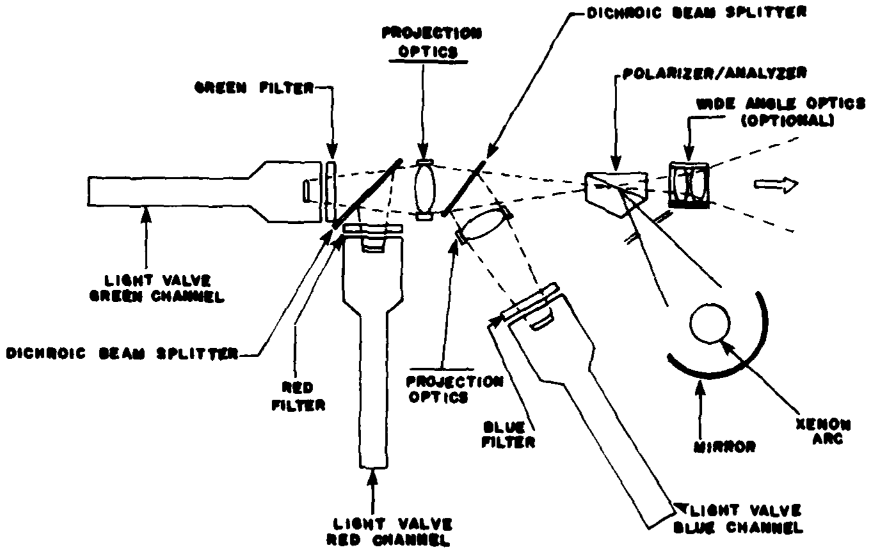
Engineering". A brief explanation of a smectic light valve follows. A smectic liquid crystal light valve receives local heating (normally from a laser), and the molecules of the crystal are placed in some randomly oriented order by the thermal-heating. If the cooling process of the crystal is slow, the molecules realign themselves in parallel planes or layers. This produces a clear state within the crystal and allows light to be transmitted; the "on-state". If the cooling is rapid the molecules of the liquid crystal light valve assume a random orientation (as opposed to parallel in the "on-state") and light is not transmitted; the "off-state".

Color images are generated with liquid crystal light valves through the use of multiple channel projectors and appropriate selection of filters. Both Hughes and Singer are currently developing full-color versions of their respective products. The Hughes system uses two liquid crystal light valve channels, one red and one green, to produce additive images with up to four colors; yellow and orange are produced by different combinations of the two primary colors (red and green). The Singer system employs two liquid crystal light valves (LCLV) to produce four colors; three colors for display information (red and green, a combination of the two to produce yellow) on a fourth color background. This system uses a YAG laser to address an assigned light valve channel, either selectively or simultaneously.

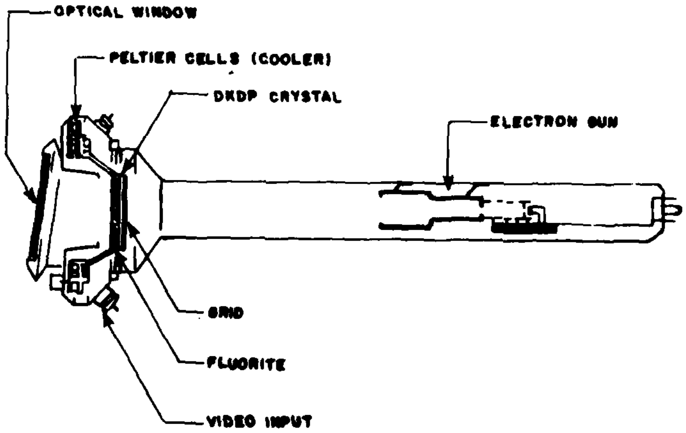
The brightness of these two systems is comparable; both yield approximately 800 lumens with the output luminance being dependent upon the size of the projection lamp. Resolution of the two systems is determined primarily by the light valve. In the Singer system, the light valve can deliver approximately 2500 TV lines; the Hughes system delivers 1000 TV lines.

A solid-state light valve has been developed by Sodern using a photo-DKDP (potassium dideuterium phosphate) thin crystal by Sodern. This device allows the display of video images in both black and white (monochrome) and full-color. Modulation of incident light on the target crystal is obtained by polarization of the DKDP crystal. When an electric field is applied to the light valve, the characteristics of the solid-state DKDP crystal change by the bi-refringence effect. The crystal is scanned by an electron beam and produces modulation of the illumination according to the video signal applied (Figure 9).

This system uses three Titus light valve channels with red, green, and blue filters (red, green, and blue channels) to produce full color displays. Each channel receives its illumination from a common xenon lamp and the resulting signals/images are mixed at the



SODERN SOLID STATE LIGHT VALVE OPTICAL SCHEMATIC (a)



TITUS LIGHT VALVE (b)

Figure 9. SOLID STATE LIGHT VALVE OPTICAL SYSTEM

projection lens for large screen display. A schematic of the light valve is shown in Figure 9b.

The solid-state light valve is reported to deliver brightness outputs of 1500 to 1900 lumens, depending upon the intensity of the xenon lamp chosen for illumination of the system. The system has been successfully demonstrated at 525 and 625 TV lines. Higher resolutions may be obtained by using other video amplifiers. The first production model, using a 1000 line TV raster, was delivered in 1982.

Light valve large screen display systems range in price from $55,000 to $300,000, depending upon the technique used. Monochrome systems are at the low end and four-color and full-color systems are at the high end.

A light emitting diode (LED) is a solid state device that emits light when a forward bias voltage is applied. Electrons are ejected across a potential barrier and recombined with holes, emitting radiation. The intensity of luminescence is directly proportional to the forward bias current. These solid state devices have been packaged into modules.

A militarized LED display system has been developed and produced. This type of display is constructed of modules assembled into flat-panels which can range in size from several square inches to several square feet. Large screen displays have been fabricated using this approach and are available upon special order. The individual modules used to make these displays are flat, plug-in units with LEDs mounted on the front surface and associated electronics mounted in the same unit. Monochrome displays are available with resolution of 33 lines per inch.

These displays are also available in monochrome color versions of red, green or yellow (yellow obtained by mixing red and green). Multicolor displays are also available in various sizes from several square inches to several square feet. Resolution of the color modules is 20 to 22 lines per inch.

The monochrome and three-color modules are 3.66 cm by 7.32 cm and provide 2048 display pixels arranged in a 33 by 64 line matrix.

Large screen LED displays provide high brightness (equivalent to approximately 1800 Lumens) and high resolution (32 lines per inch on a 6 by 6 foot display; equivalent of 2300 lines). At the present time several large tactical displays of this type are being used by the US Army in Germany.

Acquisition costs for this display (~2′ by 3′) are $250,000. A 6′ by 6′ display could cost as much as $1,000,000.

Individual modules range in price from $800 to $1000, depending on whether they are monochrome or color modules. The manufacturer states that each module has a useful life of approximately 76,000 hours (this assumes that no more than 10% of the total pixels have failed with no two failures adjacent to one another within a module).

Plasma panel displays use a gas discharge as a light source. The panels are fabricated by sandwiching a neon based gas between two glass substrates. A transparent dielectric insulates the x-y array on each substrate from the gas. In forming the sandwich, the two substrates are assembled so that the electrode array of one is orthogonally oriented to the electrode of the other, forming a matrix array.

Plasma displays are presently limited to monochromatic images and the brightness is adjustable in discrete step functions. Present manufacturing methods produce displays as large as 2 meters by 2 meters with resolution characteristics up to 60 pixels per square centimeter and peak brightness of 75 foot lamberts (approximately 2700 lumens). Life expectancy of plasma panels has exceeded 20,000 hours. Multicolor displays (red, green, white and blue) are under development and should be available in late 1983. Costs of monochrome plasma panels are approximately $10,000 per square foot. The cost for multicolor plasma displays has not been determined.

SECTION 3

LARGE SCREEN DISPLAY COMPONENTS UNDER DEVELOPMENT

Several new large screen display components have been identified including new screen materials as well as new display components suitable for use in large screen display units.

Freen Screen Manufacturing, Inc. developed a new screen material for rear projection systems; the new screen provides high gain without limiting viewing angle and allows the display to be used in high light ambient areas. Litton Industries and Philips Research Laboratories (West Germany), have each developed solid-state components based on magneto-optics principles for use in large screen display systems. These devices, because of their inherent low power, reliability, ruggedness, and potential low production costs are particularly suited to military and industrial applications. Lucitron, Inc. has developed a new flat-panel device called gas-electron-phosphor (GEP). This device termed "Flatscreen", delivers a savings in the cost of electronics when compared to other flat-panel or plasma devices because of a unique matrix addressing circuitry which significantly simplifies fabrication.

Magnavox Government and Industrial Electronics and Photonics Technology, Inc. have jointly developed a technique for fabricating large flat panel plasma displays. They report that the capability now exists to produce large flat AC gas discharge display panels sizes up to one meter diagonal with resolutions available up to 1600 pixels per square centimeter and brightness in the order of 2700 lumens. Life expectancy of the display is stated to be over 20,000 hours. A three foot diagonal panel is currently under development.

A description of each new component follows.

The Freen Screen Manufacturing Company fabricated a rear projection screen that uses an assemblage of lenticular lens panels secured to a rigid substrate. This device provides uniform light distribution to predetermined audience fields, the gain of the screen is flat as a function of bend angle, over a large field of view (see Appendix D),and the reflected ambient light is significantly attenuated when compared to standard rear projection screens. The screen surface contains horizontal black stripes adjacent to the lens panel, creating a screen that is 50% matte

black. The horizontal black lines absorb the normal reflected ambient light, so the screen can be used in relatively bright room conditions.

Litton Data Systems has developed a new magneto-optic solid state alterable memory device. This device, designated as the Litton L-135, can be used as a high resolution light valve within a display, projection or optical processing system. It uses garnet films grown on non-magnetic substrates (Figure 10). The garnet films can be magnetized perpendicular to the film plane. When polarized light is transmitted through the film, the Faraday effect of the film causes the polarization of the light to be changed in a manner dependent upon the direction of magnetization of the film. By adding an analyzing polarizer to view the emerging light, differentiation between the two magnetic states can be detected. In effect, a light valve is produced.

Litton predicts that this device will have applications in the display, numerical, computational, and optical processing fields. In the display field, the use of the device as a light valve is the most logical. Arrays can be designed and built in sizes containing 1024 by 1024 pixels or more. The device's low power, reliability, ruggedness, and temperature insensitivity make it particularly suitable for military applications.

The Litton L-135 is in an early stage of development by the Litton Advanced Research Group. The existing model is a 48 by 48 millimeter array of five mil pixels employing a projection technique. Resolution of up to 2048 lines is anticipated. The present device is a monochrome display projector, but full color arrays are planned for future development. The array can be addressed by either random x-y or raster scan and may be used for alphanumerics or graphics.

The electronic device is fast (switching time is 50-100 usec for 512 by 512 array), and stable over a wide temperature range (-100° to $+100^{\circ}$C). Because this device can be fabricated employing semiconductor techniques, Litton expects the cost of the device to be about the same as an equivalent sized integrated circuit.

Philips Research Laboratories of Hamburg, West Germany has developed a new magneto-optic solid state device with potential applications in the printing and display fields. This device is fabricated by depositing a small quantity of magneto-optic iron-garnet film on a single crystal transparent substrate (gadolinium gallium garnet). The film is etched to form small light sensitive cells. The area between the cells is covered with a metal film to block the light.

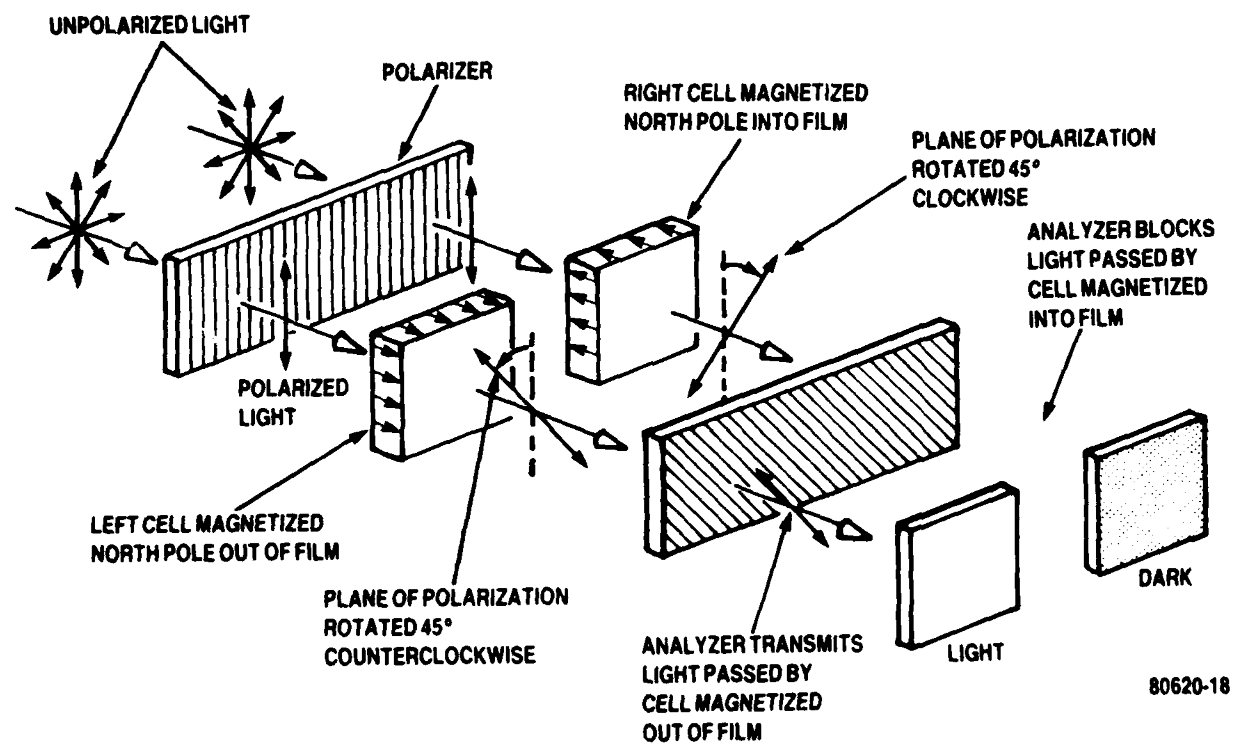


Figure 10. LITTON MAGNETO-OPTIC SYSTEM

The film's magnetization can be either parallel or non-parallel to the normal of the film. If linearly polarized light traverses the cell, the light's plane of polarization is rotated either to the left or right (see Figure 11) depending on the direction of magnetization. This is called Faraday Rotation and is the basis for light switching.

The cell is sandwiched between two polarizing foils, the first producing polarized light. Emerging from the cells is light with different planes of polarization for different directions of magnetization. The second foil blocks the light associated with one plane of polarization and transmits the other. A thermomagnetic means is used to switch from one magnetic direction to the other. The direction of magnetization switches within a fraction of a second.

Philips has demonstrated the device in a printing application and has produced information of photographic quality. They have also developed and demonstrated a projection-type iron-garnet display with 256 by 64 picture elements. Information can be written into the display with a microprocessor-controlled pattern generator activated from a keyboard. Philips expects to design and build arrays in sizes containing 1024 by 1024 pixels or more.

The Philips device is solid state and uses no moving parts. Like the Litton product, it is particularly suited to military applications because of its low power requirements, ruggedness, and temperature insensitivity. Two-dimensional arrays can be applied to projection displays for data output terminals and other applications. Due to their inherent memory, additional image storage devices are not required and a display using these components is flicker-free.

Resolution up to 2048 lines is predicted with this magneto-optics technology. Full color displays are planned for future development. Pricing information has not been determined at this time. Expected life of these devices, a typical array, exclusive of the electronics, is expected to exceed 30,000 hours.

Lucitron has developed a large screen, flat panel unit for displaying computer-generated alphanumerics and graphics as well as television pictures with full gray scale.

The device uses a recently developed technology called gas-electron-phosphor to produce bright pictures (200 to 400 lumens for white, higher for green). A gas discharge is used for scanning

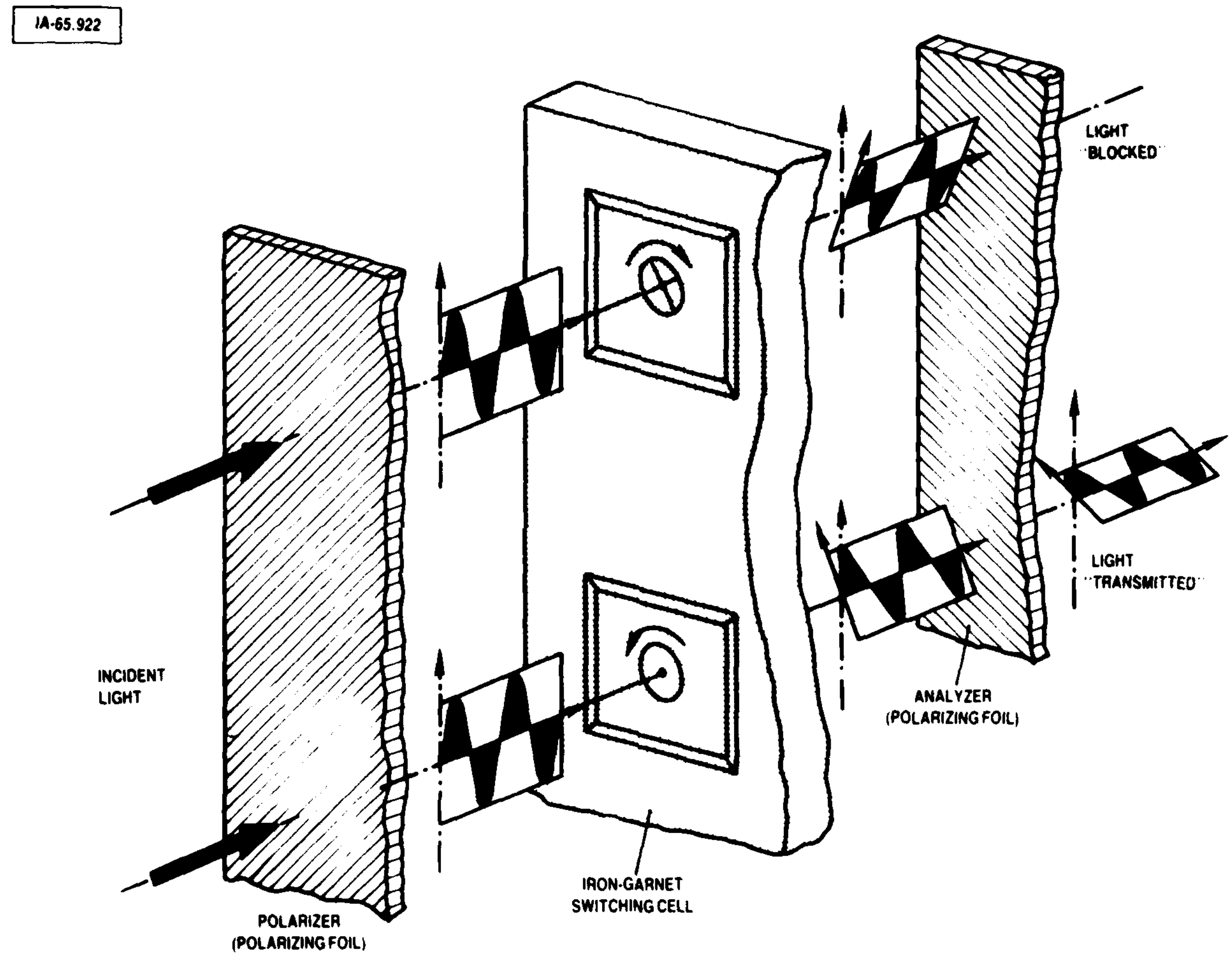


Figure 11. PHILIPS MAGNETO-OPTIC SYSTEM

and selection. Electrons, extracted from a cold-cathode glow discharge, are accelerated to produce light from conventional CRT (cathode ray tube) phosphors.

Lucitron's initial product has a viewing area of approximately 4.0 square feet (active area of 20.5" by 27.6"). Resolution is 12.5 elements per inch vertically and 18.5 elements per inch horizontally; a total of 131,072 dots in 256 rows by 512 columns. This yields 25 rows of 85 characters each based on 5 X 7 dot characters of 0.56 inch high. According to the manufacturer the matrix display has no distortion or defocusing at the corners.

The "Flatscreen" provides a high degree of multiplexing, resulting in fewer drive circuits. The electronics include 60 active drive circuits: 16 horizontal and ten vertical scan drivers; two scan reset drivers and 32 video drivers. In addition, the unit has 36 DC leads, 32 of which are cathode leads. Most other matrix techniques require a driver for each column and row.

Electrical interfacing is by RS-170 or separate video and sync inputs for picture video. For graphic or alphanumeric display generated by a computer, the unit requires an additional dot clock (fed to an additional sync input) to synchronize the panel horizontal scan with the source horizontal scan. Power consumption is less than 1000 watts.

Initial units are monochrome; color will be available in late 1983 or early 1984. Cost of the initial production monochrome units (34" diagonal display) is $33,000. Life expectancy of these units is projected to be 30,000 hours or more by the manufacturer. Applications include military command and control areas, management information systems, process control systems, etc.

Magnavox Electronics Systems and Photonics Technology have developed a technique of fabricating large flat panel displays up to 6' by 6'. These large AC-plasma displays are flat, compact, rugged, and highly transparent with rear-map projection capability and are suitable for military applications.

Plasma panel displays use a gas discharge approach as a light source. The panels are fabricated by sandwiching a neon based gas between two glass substrates. A transparent dielectric insulates the x-y array on each substrate from the gas. In forming the sandwich, the two substrates are assembled so that the electrode array of one is orthogonally oriented to the electrode of the other.

All display panels have inherent memory which is maintained by a periodically reversing sustain voltage applied to all x and y electrodes in the matrix array. The amplitude of this voltage is adjusted to a level such that the gas between the dielectric layers does not break down in the absence of an electrical wall charge on the dielectric surface.

To turn a selected pixel cell "on", a pair of opposite polarity address pulses, with appropriate amplitude and timing, are superimposed on the sustaining waveforms of the x and y electrodes which define the selected pixel. The combined voltages at the addressed pixel then exceed the breakdown voltage of the gas, resulting in ionization and collection of charges at the dielectric walls of the selected pixel cell. This "wall" charge produces an effective electrical bias approximating the peak sustainer voltage. On the next reversal of the sustaining waveform this pixel cell is again subject to a voltage equal to the peak-to-peak sustained waveform. This voltage is sufficient to ionize the gas and collect a wall charge bias, equal to the peak sustained voltage, but of the opposite polarity. On each successive sustain waveform reversal, this pixel, and all other pixels which were previously left in the "on" state, will ionize, produce light, and collect a memory "wall" charge without the application of refresh address pulses.

To erase a pixel cell, the applied x and y address pulses are manipulated in time and voltage so as to neutralize the memory "wall" charge.

Plasma displays are presently limited to monochromatic images and brightness is adjustable in discrete step functions. A product is available in 1m by 1m size with 23.6 pixels per centimeter.

The vendor states that present manufacturing methods have resulted in displays as large as 2m by 2m, resolution characteristics up to 1600 pixels per square centimeter, and peak brightness in the order of 2700 lumens. Life expectancy of plasma panels have exceeded 20,000 hours. Multicolor displays (red, green, white, and blue) are under development. Costs of monochrome plasma panels run approximately $85,000 per square meter.

SECTION 4

COST DRIVERS IN PERFORMANCE REQUIREMENTS

Several important performance parameters of large screen displays surface when defining cost-drivers. They include luminance, resolution, update speed, color, display load, and consumable items. Each of the various large screen technologies will be examined in relationship to these parameters to determine how they affect the limits of performance.

Large auditoriums generally require high ambient lighting, and as a result, large screen displays are required to present high contrast display presentations to the dispersed audience. The key parameters involved are contrast ratio and rapid update time. Contrast ratio is defined as the ratio of display brightness to viewing screen background ambient. The display brightness of a large screen is related to the screen size and screen gain. Also related to these parameters are projector throw distance, projector mode (front or rear of screen), display luminance, and audience viewing angle.

The display luminance is related directly to the product of screen size and display luminance (at the center of the screen) and screen gain. Rear projection provides an improvement in display contrast over front projection. Some rear projection screens also provide relatively high gain with increased viewing angle.

Single CRT projection display systems are limited in brightness output to approximately 250-350 lumens. The display luminance can be improved by using a projection lens of lower f-number which improves the light gathering efficiency of the system or by increasing the CRT anode voltage to produce brighter images.

General purpose projection lens are generally built with f-numbers between 0.8 and 1.0 and are normally available as off-the-shelf items. High quality lens with f-numbers less than 0.8 require special orders and can add $25,000 to $35,000 to the cost of the projector. In order to increase CRT brightness, faceplates capable of dissipating the added heat produced by the higher operating voltages are bonded to the CRT. Special faceplates, such as one molded from sapphire or special Schott glass, can increase the cost of CRTs by several orders of magnitude (conventional CRTs approximately cost $3000; special purpose CRTs approximately $25,000).

Large screen displays that use TV or random plot techniques can be updated within the amount of time required to load the new display into the display refresh memory. Normally, this time is less than one second for displays that are linked to an interfacing computer using typical I/O rates. The one-second update time cannot be satisfied with systems using mechanical deflection techniques. These systems require approximately 8-10 seconds to update a display image.

High performance CRT displays that use a high brightness CRT and a low f-number deliver between 100 lumens to 350 lumens on a display screen of 35 to 50 square feet. The use of high gain screens (especially the rear projection type) improve display contrast. The low performance large screen displays provide lower luminance and low resolution (<300 TV lines and <100 lumens). Multiple projectors can be configured to increase display luminance or to provide color presentations. Display resolution of 1000 TV lines can be provided with high performance CRT projector displays.

Present LED devices are limited to brightness of approximately 30 foot-candles. In order to obtain higher brightness levels additional solid-state drivers must be coupled together to deliver high drive currents. Present cost for a typical monochrome standard brightness LED module is $1000; a module capable of producing a brightness of 100 foot-candles costs more than $3000.

Oil film light valves available today for both monochrome and color presentations are capable of generating between 800 TV lines and 1000 TV lines. This type of technique has produced luminance of 550 to 7000 lumens. Problems limiting brightness because of failure in oil film breakdown have been resolved.

The liquid crystal light valve has made significant progress in the last several years. Resolutions are available between 1000 and 2500 TV lines, dependent upon the manufacturer. Brightness in the range from 800 to 1000 lumens is available in a four-color display. Full-color projectors are being developed. Cost of these units is relatively high and range from $300,000 to $400,000. A solid-state light valve has been developed capable of 1700 or 1900 lumens of brightness with a resolution of 525 or 625 lines. Projected cost of this unit is $200,000.

Large screen displays operated in both ground-based and sea-based environments perform acceptably when built in a ruggedized military version. Temperature qualifications provide no significant problems, however high humidity can produce arcing at high CRT anode voltages. (The cost of color large screen displays using multiple projectors varies directly to the number of projectors.) Multiple

projectors can present registration problems for color presentations. Several manufacturers have solved this problem with sophisticated electronic circuitry.

Cost of operation can vary between $1 to $100 per hour depending upon the particular technology employed and the particular model of the vendor's product.

In selecting a system for a particular environment one should address the contrast ratio of the display image, the resolution of the displayed image, the viewability of the image by the audience, the maintainability of the equipment, and the operating cost per hour. A single system of any type costs significantly more than if purchased in quantity, because of development costs, etc. For instance, one system of a particular large screen display using a plasma technology costs approximately $87,000; 100 systems cost only approximately $35,000 per system.

If any or all of the new large screen display technologies become cost effective, we will see many more of these devices in command, control and communications centers. In addition, the commercial application will also increase dramatically.

APPENDIX A

COMPILATION OF LARGE SCREEN DISPLAY CHARACTERISTICS

In the following section the characteristics of large screen display equipment which were addressed during the survey are described. Qualitative and quantitative statements of brightness, resolution, and acquisition costs are presented for each product. These qualitative statements are defined as follows:

Resolution: (TV Lines)	Low	0 to 625
	Moderate	625 to 1000
	High	1000 to 3000
	Very High	>3000
Brightness: (Lumens)	Low	0 to 300
	Moderate	300 to 1000
	High	1000 to 3000
	Very High	>3000
Cost:	Low	0 to $25,000
	Moderate	$25,000 to $250,000
	High	$250,000 to $1,000,000
	Very High	>$1,000,000

Tables I, II, and III provide a summary of the vendors surveyed and the performance associated with this equipment.

Vendor	Page
Aydin Controls	33
Avionics Systems Corporation (Gretag/Eidophor)	35
Electronics Systems Products, Inc.	38
Ford Aerospace and Communications Corporation	40
General Atronics Corporation/Sodern	44
General Dynamics	46
General Electric Company	49
Hughes Aircraft Company	52
Kalart-Victor Corporation	55
Litton Data Systems	57
Singer Company	59
Videpro International Products Limited	62

Aydin Controls
401 Commerce Drive
Fort Washington, Pennsylvania 19034

Contact: Joseph J. Taylor, Director of Marketing
Lee Craymer, Industrial Sales Manager

Telephone: (215) 643-0600

Display System: Model 8063, Monochrome
Model 8063-C, Four-Color

Aydin Computer Systems manufactures the Model 8063 series of Large Screen Projection Color Display Systems. The company's product line includes one, two or three single-color refractive optics projectors; when used in combination of multiple projectors, a multicolor display is produced by superposition of images. The single projector provides a monochrome display.

In the 8063-C system two CRT projectors, red and green, produce a four-color projection display: red, green, yellow, and orange. A third projector, blue, may be added to produce a full-color display. All projectors are rigidly fastened to a common mounting assembly at the optimum angle dictated by the desired throw distance. The images are electronically compensated due to the off-axis projection angle. Each projector incorporates a direct-writing CRT/lens assembly driven by random stroke X and Y deflection signals and intensity and color control signals.

Characteristics of the Aydin 8063-C system are given below:

Screen Size: Up to 1.8m X 1.8m

Projection Technique: Front or Rear

Color: Four-color using two projectors
Full-color using three projectors

Luminous Output: 300 Lumens

Update Time: One TV frame

Resolution: 1000 TV lines

Image Mechanism: Direct image

Display Technique: Raster scan

Drift: Less than 3%

Brightness Uniformity: 2:1 from center of screen to edge

Contrast Ratio:

$$\text{Contrast Ratio} = \frac{\text{Display Brightness}}{\text{Display Ambient}} = B_D/B_A$$

Contrast Ratio = 5:1 (Typical)

X-Radiation: Conforms to HEW Radiation Performance Standards 21 CFR

Initial Cost: Model 8063 Monochrome, $45,000
Model 8063-C Four-color, $85,000

Number of Units in Field: Model 8063 - 20
Model 8062-C - 4

Consumables: The high brightness CRT (high failure rate component) is reported to cost $2000. Assuming replacement at 1000 hours (the warranty period) operating cost per hour is:

Model 8063 - $2
Model 8063-C - $4

Commentary: The Model 8063-A multi-color large screen projection system is a new entry in their product line. Three projection CRT units provide full (eight) color capability by employing CRTs with different phosphors: red, green, and blue. The convergence of the three CRTs produce red, green, blue, yellow, orange, cyan, magenta, and white colors. The cost of this system is stated to be $120,000. Using the procedure described earlier, the operating cost of this unit is estimated to be $6/hour. No units presently exist in the field.

Avionics Systems Corporation
Division of Lear-Siegler
32 Fairfield Place
West Caldwell, New Jersey 07006

Contact: Barry B. Lane, Contracts Administrator
Lenord Blascovich, Systems Engineer, Ext. 305

Telephone: (201) 575-8000, Ext. 203

Display System: Gretag/Eidophor Large Screen Television Projection Screen System

The Eidophor (Gretag Corporation, Switzerland) manufactures a product line of high-cost monochrome and color large screen television projection systems: the Models 5170, Model 5171 and Model 5180. These systems are commercial product line items and are presently available as off-the-shelf items. High brightness and moderate resolution are two characteristics of these devices. The devices have been developed for the closed circuit Television and Theatre Market.

Each Gretag/Eidophor color projector employs three separate electron-gun light valves in which the individual color images are separately written on a thin oil layer on concave mirrors in each channel. White light from an xenon lamp is split up by means of colored filters and dichroic mirrors into red, green, and blue light. Each color beam is directed to its appropriate channel where it is focused onto the oil-film-surfaced mirror and reflected to the viewing screen by projection optics.

The Gretag/Ediphor projector operates in the television standards CCIR 625 lines and EIA 525 lines raster scan mode only. Following is a summary of the characteristics of these projectors:

Screen Size: Up to 30' X 40'

Projection Technique: Front or Rear

Color: Full NTSC Color

Luminous Output: Model 5170 (Full-color) 3600 Lumens ±10%
Model 5171 (Full-color) 7000 Lumens ±10%
Model 5180 (Monochrome) 4000 Lumens ±10%

Contrast Ratio:

Contrast Ratio = B_D/B_A

100:1 at center of screen
75:1 at edges of screen

Update Time: One TV frame time

Resolution: 800 lines at center of image
600 lines at the corners of image

Image Mechanism: Oil Film Light Valve

Display Technique: Raster scan

Drift: Less than 2%

Color Registration: Red and Blue with respect to Green, in each direction, measured between points of maximum brightness; better than 0.10% of picture height within a circle of a diameter of 0.80 by picture height, better than 0.25% over rest of the picture area.

Brightness Uniformity: 2:1 from screen center to screen corners

Aspect Ratio: 4:3, picture width/picture height

X-Radiation: Conforms to HEW Radiation Performance Standards 21 CFR. Manufacturer claims negligible x-radiation due to low anode potential required to operate the light valve.

Initial Cost: Distributor states that with standard equipment package:

Model 5170 - $450K
Model 5171 - $505K
Model 5180 - $190K

Number of Systems in Field: "Several Hundred"

Power Consumption: Model 5170 - 5.6KVA
Model 5171 - 13.5KVA
Model 5180 - 5.6KVA

Three major components requiring the most frequent replacement are the xenon lamp and the cathode cartridge and

the vacuum oil. The costs and replacement times as given by the distributor are:

	Model #	Cost	Replacement
Xenon Lamp:	5170	$830	1000 hours
	5171	$4500	500 hours
	5180	$830	1000 hours
Cathode Cartridge:	5170	$180	100 hours
	5171	$180	100 hours
	5180	$180	100 hours
Vacuum Oil:	All	$450	1500 hours

Refurbishable Items:

	Cost	Replacement
Modulation Lens	$385	1500 hours
Port Glass Window	$380	1500 hours
Cathode Changer	$4500	1500 hours
Oil Cartridge	$800	1500 hours
Electron Gun	$2000	7000 hours

The operating costs calculated from the above are given below, together with those quoted by the distributor.

Operating Cost:	Model	Calculated Cost/Hour	Distributor Cost/Hour
	5170	$17	$18
	5171	$40	$25
	5180	$32	—

Warranty: The distributor states that Gretag/Eidophor projectors are warranteed to be free of defective material for one year. The cathode cartridges are warranteed for 100 hours and the xenon lamps for 1000 hours or one year.

Additional Comments: The Eidophor Monochrome Model EP-8-SQ has been replaced by the Model 5180 monochrome project. The latest model employs the same reflective Schlieren optics technique as the full-color versions. The 5180, being monochrome, utilizes only one channel while the color projectors employ three channels. The luminous output of the new monochrome projector is 4000 lumens as compared with 900 lumens for the EP-8-SQ.

Electronics Systems Products, Inc.
One Tico Road
Titusville, Florida 32780

Contact: Debra Day, Area Manager
Richard Smith, Technical Staff

Telephone: (305) 269-6680

Display System: Aquastar III B

The Electronics Systems Products, Inc. manufactures the Aquastar III B Video Projector. This system offers a lightweight, low-cost, low brightness unit with a reported resolution of 600 lines RGB-330 NTSC video.

The Aquastar III B is a self-contained three CRT refractive projection system. It utilizes liquid-coupled lens and liquid-cooled tubes in a new design and provides a relatively high luminance display system for a direct projection system. A summary of its characteristics follows:

Screen Size: Up to 19′ X 25′

Projection Technique: Front or Rear

Color: Full-color

Brightness: Calculated to be 8fl as measured from the center of the screen using a 7.5′ x 10′ screen with a 1.5 gain.

Luminous Output: 400 Lumens

Contrast Ratio:

$$\text{Contrast Ratio} = {}^{B_D}/{}^{B_A}$$

$$= 30:1 \text{ (typical)}$$

Resolution: 600 lines RGB-330 NTSC Video

Image Mechanism: Direct image

Display Technique: Raster scan

Drift: Less than 2.0%

Brightness Uniformity: 2:1 from center screen to edge

Aspect Ratio: 4:3

X-Radiation: Conforms to HEW Radiation Performance Standards 21CFR

Initial Cost: Aquastar III B - $9.5K

Number of Systems in Field: ~700

Power Consumption: 300 to 400 watts, 115V 60Hz

Consumables: The CRT is assumed to be a high failure rate consumable item. The cost of each CRT is reported to be $400. Assuming that each CRT is replaced at the end of the warranty period of 1000 hours, the calculated operating cost per hour is approximately $1.

Ford Aerospace and Communications Corporation
Western Development Laboratories Division
3939 Fabian Way
Palo Alto, California 94303

Contacts: William H. Wahrhaftig, Manager, Data Display Programs
Donald Pelner, Advanced Display Systems

Telephone: (415) 494-7400 X4255

Display Systems: ATP-1000, Single CRT Projection System
ATP-3000, Three CRT Projection System (Three-Pack)
ATP-6000, Six CRT Projection System (Six-Pack)

The Ford Aerospace and Communications Corporation has developed three CRT projection systems, the ATP-1000, the ATP-3000 and the ATP-6000. All three units utilize commercially available components and are constructed on special order. The Three-Pack System (ATP-3000) was developed under a contract from the Navy Range Operation Display System (RODE) and the Six-Pack (ATP-6000) as part of the Air Force's Alternate National Military Command Center Program (ANMCC).

At the present time, two ATP-3000's have been sold and are in use; one at Nellis Air Force Base, Nevada and one at Point Mugu, California. The dual ATP-3000 at Fort Richie was furnished with sapphire faceplate CRTs. The manufacturer has been referring to this unit as a Six-Pack (ATP-6000). Many ATP-1000's, the monochrome unit, are being used by the US Navy.

The systems display presentation is generated by optically magnifying the separate red, green, and blue images which appear on the CRTs located in the projection heads. Full NTSC color is derived from the three primary color phosphors. The units utilize a television raster for generating alphanumerics and graphics and are capable of producing a seven color display.

Both models function identically; however, the larger unit offers a completely redundant system with a reported twice the picture brightness as the smaller unit. Since the Six-Pack is essentially a dual Three-Pack, only the characteristics of the smaller unit will be discussed. The ATP-1000 is discussed under additional comments. A summary of the ATP-3000 (Three-Pack) is presented below:

Screen Size: 6′ by 8′ with a throw distance not less than 16′

Projection Technique: Front or rear (folded optics are required for rear projection).

Color: Full NTSC color is derived from three primary color phosphors: Green, P1 phosphor; Red, P22 phosphor; Blue, P48/P4 phosphor.

Brightness: 15 foot lamberts for white light on a screen of 6′ by 8′ screen gain of 2.5 with fresnel lens. Measurements were made at maximum beam power. The fresnel lens is used to minimize luminance drop off at the outer areas of the viewing screen when operating in the rear projection mode. The fresnel lens is not required when functioning in the front projection mode.

Luminous Output: 300 Lumens

Display Technique: High brightness CRTs with projection optics.

Contrast Ratio:

$$\text{Contrast Ratio} = B_D/B_A$$

For unity gain screen:
Front Projection - 3.5:1
Rear Projection - 15:1

Update Time: One frame time

Resolution: 1000 TV lines

Image Mechanism: Direct image

Display Technique: Raster scan

Repeat Mode: 1029 lines, 60 fields/30 frames/second

Linearity: Center = 1 percent
Outside = 2 percent

Drift: 1% at $72^oF \pm 5^oF$ after one hour warm-up and operating with a fixed room ambient of $72^o \pm 5^oF$; using a self contained digital registration technique.

Brightness Uniformity: 2:1 variation across screen (center to edge)

Aspect Ratio: 1:1 and 4:3

X-Radiation: Less than 2.5 m/h at 50KV; conforms to HEW Radiation Performance Standards 21CRF

Power Consumption: 2300 watts

Consumables: For the ATP-3000 (Three-Pack) the manufacturer indicates that the standard (glass) projection CRTs require replacement after 2000 hours of field operation at power levels demanded to produce stated viewing screen brightness. Each CRT replacement cost is $2500. Assuming that each CRT will be replaced at the manufacturers warranty limit (1000 hours), the operating cost for the CRTs alone, with 24 hour round-the-clock use, will be greater than $7/hour.

Initial Cost: Ford Aerospace furnished the following information: Cost of an ATP-3000 (Three-Pack) system if bought in quantity (20-30 units) would be approximately $500,000/Unit. Stated prices do not include spare parts.

Ford furnished price information on the ATP-6000 (Six-Pack) is $1,000,000 in quantity of ten or more. For the ATP-1000, cost has been quoted as $150,000

Number of Units in Field: ATP-1000 - 15 plus 11 on order
ATP-3000 - 2
ATP-6000 - 1

Warranty: The CRTs are ranteed by the manufacturer, Thomas Electronics, for 1000 hours.

Additional Comments: Precise color registration is reportedly obtained from unique digital correction circuitry in both the ATP-3000 and ATP-6000. This circuitry is provided to assist the calibration technician in registering the images produced from the multiple projectors.

Using the procedure described earlier, the operating cost per hour for the APT-6000 with six sapphire faceplate CRTs is estimated to be $90/hour. This figure results from the high cost of the sapphire faceplate CRTs ($15,000 each) and the need for six CRTs required to deliver the quoted brightness.

Ford has successfully marketed the ATP-1000, a monochrome Digital Television Projection Unit (DTVPU) to several customers, including the US Navy. It was designed to meet MIL-E-16400, military specification for shipboard installation.

The single CRT projector employs a P_1 phosphor and a transmissive optical system of f/1.04. The unit has a light output of 280 lumens and a resolution of 1000 TV lines. The contrast ratio measured on a unity gain screen front projection screen with an ambient of 2.2 foot-candles on the screen is 8:1.

The manufacturer has reported that the ATP-1000 Digital Television Projection unit has received United States Navy "use approval" (will be available as an off-the-shelf item for Navy use). Cost of the ATP-1000 is $150,000.

General Atronics Corporation/Sodern
Division of Magnavox
1200 East Mermaid Lane
Philadelphia, PA 19118

Contact: Donald A. Couvillion, Product Manager

Telephone: (215) 233-4100 X259

Display System: Sodern/Titus Solid State Light Valve

Sodern of Brevannes, France has developed the Sodern Visualization System from the Titus solid-state light valve. This product line is marketed by General Atronics Corporation of Philadelphia, PA, a division of the Magnavox Corporation in the USA. The device is a three channel projection system using three Titus solid-state light valves.

The Sodern Visualization System uses a red, green, and blue light valve channel to produce a full-color presentation. Each channel receives its illumination from a single xenon lamp and the produced primary color images are mixed in the projection optics for a full-color presentation. Monochrome (black and white) can also be achieved by this system with the removal of the primary color filters in each channel.

The large screen display system uses three Titus solid-state light valves, each incorporating a photo-DKDP thin crystal, which are addressed by video signals in a non-conventional manner. In conventional CRTs, or other types of light valves, the screen illuminance depends directly upon acceleration voltage, current, and line deflection time or raster rate. With the Titus solid-state light valve (a modified electron-gun device) the illuminance depends upon the video voltage only and not upon the scanning speed.

A summary of the Sodern/Titus SVS12 characteristics is as follows:

<u>Screen Size</u>: Up to 10m by 10m

<u>Projection Technique</u>: Front or Rear

<u>Color</u>: Full-color presentation; monochrome (black and white) is available

Luminous Output: Quoted values of 1500, 1900, or 2800 lumens; dependent upon xenon lamp used.

Contrast Ratio:

$$\text{Contrast Ratio} = {}^{B}D\text{ (White)}/{}^{B}A\text{ (Black)}$$

$$= 100:1 \text{ at center of screen}$$

Image Mechanism: Solid-state light valve

Display Technique: Raster scan

Color Registration: Blue and red with respect to green, in each direction, measured between points of maximum brightness; better than 0.05% of image width.

Brightness Uniformity: Better than 2:1 from screen center to screen corners.

Aspect Ratio: 4:3 picture width to picture height

X-Radiation: Conforms to HEW Radiation Performance Standards 21CFR

MTBF: 1000 hours including three light valves and xenon lamp

MTTR: 30 minutes including replacement of light valve or xenon lamp

Consumables:

The solid-state light valves have a projected cost of $10,000 per light valve and an expected replacement at 6000 hours. The 2.5 KW xenon lamp (1500 lumens projector output) has a projected cost of $4000. The life of the xenon lamp is estimated to be one thousand hours. Operating cost per hour is calculated to be $6.

Note that the replacement hours are theoretical. Sufficient data for both the new light valve and high intensity xenon lamp have not been obtained as of this date to give an exact operating cost per hour.

General Dynamics
Electronic Division
P. O. Box 81127
5011 Kearny Villa Road
San Diego, California 92138

Contact: Richard E. Thoman

Telephone: (714) 692-7211

Display System: Model 303B Display System
Model 303C Display System
Model 303F Display System

General Dynamics manufactures a series of CRT projection large screen display systems: Models 303B, 303C and 303F. These units form a commerical product line and are presently built to order. The three systems provide a high resolution, moderate brightness display presentation. The Model 303 series consists of a catadioptric optical system (the 303B and 303C also use catadioptric optics) which projects an image from a high brightness CRT. All necessary magnetics, power supplies, and projection electronics are contained within the unit.

In operation, the individual projection head accepts control and driving signals from the electronics and produces an image on the system CRT faceplate. The catadioptric optical system projects this image onto a viewing screen. The Model 303 series can operate in either a TV raster or random plot mode.

Color display images are provided with a multiple projector configuration of the Model 303C and Model 303F systems. Model 303C utilizes two projectors and the Model 303F, three projectors. Both models employ a convergence unit which corrects the input signals for off-axis projections.

The following contains a summary of the large screen display's characteristics:

Screen Size: Up to 5m by 5m

Projection Technique: Front or Rear

Color:

Model 303B, Monochromatic (color determined by phosphor selection).

Model 303C, Four-color display provided by dual projector configuration.

Model 303F, Full-color provided by a three projector configuration.

Luminous Output:

Model 303C - Green (P1 Phosphor), 18fL (225 Lumens)

Red (P22 Phosphor), 13fL (163 Lumens)

Yellow (Combination of Red and Green), 31fL (388 Lumens)

Maximum Luminance Output: (Equivalent Open Gate)	Model 303B - 560 Lumens
	Model 303C - 1000 Lumens
	Model 303F - 1200 Lumens

These reported values were measured by the manufacturer from the center of a 5′ by 5′ rear projection screen with a gain of two (2.0) and a fresnel lens behind the screen.

Resolution: All Models 303B, C and F - 1000 TV Lines

Full Scale Slew Time: 10 microseconds

Contrast Ratio:

$$\text{Contrast Ratio} = {}^{B}D/{}^{B}A$$

$$= >80:1 \text{ in Dark Room}$$

Image Mechanism: Direct image, high brightness CRT with catadioptric projection optics.

Display Technique: Raster scan or randon plot

Aspect Ratio: 1:1

X-Radiation: Conforms to HEW Radiation Performance Standards 21CFR

Update Time: One TV frame

Initial Cost: Model 303B - $ 60K
Model 303C - $120K
Model 303F - $300K

Number of Units in Field: Model 303B - 1
Model 303C - 23
Model 303F - None

Consumables: The high failure rate component in these systems is the high brightness CRT. The General Dynamic warranty on the CRT is for a life of 1500 hours. The cost of the tube is approximately $3.1K. Assuming a 1500 hour CRT life, there is an approximate operating cost per hour of $2/hour, $4/hour and $6/hour respectively for the Model 303B, C and F.

Warranty: General Dynamics warrants both workmanship and hardware for 1500 hours or one year, whichever comes first.

Additional Comments: In both the two projector and three projector models, color registration is accomplished electronically (this electronic correction is utilized to correct both off-axis projection and projector-to-projector differences.

Use of dichroic mirrors where the images of the projectors are optically mixed and transmitted to the viewing screen minimize the need for correction. This technique significantly reduces the need for electronic correction, but is more difficult to align and is not applicable to the three projection system.

Cost Data: The reported acquisition cost for the dual projector Model 303C (in production quantities) is estimated at $120K; for the three projector Model 303F, the cost is reported to be $300K.

Predicted MTBF: (Room Temperature, exclusive of CRTs)

Model	Standard Parts	High Reliability Parts
303B	1290 hours	2550 hours
303C	645 hours	1275 hours
303F	430 hours	850 hours

General Electric Company
Video Display Equipment Operation
Electronics Park, Building 6
Syracuse, NY 13221

Contact: Jerrold P. Gunderson, Marketing Manager

Telephone: (315) 456-2562

Display Systems: PJ5000 Series Color Systems
PJ7000 Series - Monochrome

The General Electric Company manufactures a line of moderate-cost monochrome and color large screen television video projectors. These devices are commercial product line items and are presently available off-the-shelf. Both the PJ5000 and PJ7000 series provide moderate resolution and moderate brightness display presentations. A new color projection system, the PJ5155 high intensity projector is currently available.

The color projectors employ a single electron gun light valve in which the three color images (green, blue, and red) images are written simultaneously upon the same fluid control layer (an oil film) in the form of diffraction gratings. The resultant optical spectra are selectively filtered at the output plane by vertical and horizontal slots to produce the desired colors. The image is then projected by a refractive optics projection lens to the display screen. Thus, three simultaneous and superimposed primary color images are projected to the screen as a completely registered full-color picture.

The principle of operation for the monochrome projector is basically the same as for the color projector except that the color generating medium has been eliminated.

A summary of these large screen projectors characteristics is as follows:

Screen Size: Up to 400 square feet

Projection Technique: Front or Rear

Color: Full-color plus monochrome

Luminous Output: PJ7000 750 Lumens
PJ5050 560 Lumens
PJ5155 1275 Lumens

Constrast Ratio:

Contrast Ratio = $^{B}D/^{B}A$

Contrast Ratio = 75:1 Screen Center

Contrast Ratio = 50:1 Screen Edge

Image Mechanism: Sealed oil medium light valve

Display Technique: Raster scan

Update Time: One TV frame time

Resolution: PJ7000 Series - 1000 lines
PJ5000 Series - 800 lines
PJHI Series - 1000 lines

Scan Mode: 525/625 and 1000 line rasters

Drift: Less than 2.0%

Color Registration: Single color gun - none

Brightness Uniformity: 2:1 from center to edge

Aspect Ratio: 4:3

X-Radiation: Meets requirements of HEW Radiation Performance Standards 21CFR

Initial Cost: PJ7100 Series (Monochrome) - \$55K-\$67K
PJ5000 Series (Color) - \$62K-\$81K
PJHI Series (Color) - \$85.5K

Number of Units in Field: Monochrome Projectors - 80
Color Projectors - 800
High Intensity Color Projectors - None

Consumables: Two components requiring replacement are the xenon lamp and the sealed light valve. Replacement costs are as follows:

Sealed Light Valve:	Color	\$16K
	Monochrome	\$15K

Xenon Lamp: $750

Operating cost per hour is calculated to be less than $5 for both the PJ5000 and PJ7000 series projectors.

Warranty: The GE projectors are warranteed to be free of defective materials and workmanship for one year. The light valve is warranteed for 4500 hours on a prorated basis. The xenon lamp is warranteed for 1000 hours or one year.

Additional Information: The General Electric Company has developed a new High Intensity Color Projector, the PJ5155. This unit has a reported luminance output of 1300 lumens. The higher brightness has been obtained by a re-design of the xenon reflector assembly, plus a new high intensity xenon lamp and a modification of the light valves internals.

The new light valve for the high intensity projector series is the same physical size as the present light valve and can be used as a direct replacement. The estimated cost of the new light valve is $17,800 and replacement is recommended at 3000 hours. The higher intensity xenon lamp for the unit is estimated at $1000 with replacement at 1250 hours.

Operating cost per hour for the PJ5155 is estimated to be approximately $7.00

Note that the replacement hours are theoretical. Sufficient data for both the new light valve and high intensity xenon lamp have not been obtained as of this date to give an exact operating cost per hour.

Hughes Aircraft Company
Ground System Group
P. O. Box 3310
Fullerton, California 92364

Contact: E. W. Opittek, Manager, Large Screen Displays

Telephone: (714) 732-3101

Display System: Hughes HDP-4000 Large Screen Display

The Hughes Aircraft Ground System Group has developed a Large Screen Color Display, the HDP-4000. This is a third generation system based on the Hughes Liquid Crystal Light Valve.

The HDP-4000 utilizes two additive color channels with liquid crystal light valves to produce up to four colors. Typically the primary colors are red and green. Yellow and orange are the resultant of mixing the two primary colors. Registration of the primary colors is achieved by a digital correction system. It employs digital horizontal and vertical interpolation between stored correction values for color convergence. A microprocessor aided alignment procedure minimizes time required for convergence of projector outputs.

The system utilizes two additive color channels combined with liquid crystal light valves, electronically addressed to modulate the light from a single xenon arc lamp. Optics coupled with an oil-immersion prism project color-filtered light on the display screen. A display resolution of 1024 X 1024 elements is accomplished by the optical system comprised of the liquid crystal light valve and high-resolution fiber optic CRTs driven from a digital bit memory.

The HDP-4000 is a raster scan, 1024 X 1024 addressable display element color projector capable of interfacing with a wide variety of data sources. The system will accept data and convert this data into alphanumerics and graphics for display presentation. The LCLV large screen display characteristics are as follows:

Screen Size: 1.2m X 1.2m to 3.7m X 3.7m (The screen size is a function of the projection lens and the throw distance).

Projection Technique: Front or Rear

Luminous Output:

Red	165 lumens
Green	335 lumens
Yellow	500 lumens
Orange	330 lumens

Contrast Ratio:

Contrast Ratio = $^{B}D - {}^{B}A/{}^{B}A$

Contrast Ratio (Red)	=	7:1
Contrast Ratio (Green)	=	11:1
Contrast Ratio (Yellow)	=	20:1
Contrast Ratio (Orange)	=	11:1

(Calculated contrast ratio with 0.5 fl background ambient)

Display Technique: Raster scan

Image Mechanism: Liquid Crystal Light Valve photo activated with refractive projection optics.

Resolution: 1024 lines

Drift: Minimal

Digital Positioning: 1024 X 1024 picture elements

X-Radiation: Conforms to HEW Radiation Performance Standards 21CFR

Brightness: (2.4m X 2.4m Unity Gain Screen)

Red	Three foot lamberts
Green	Five foot lamberts
Yellow	Eight foot lamberts
Orange	Five foot lamberts

Initial Cost: Cost of the HDP-4000 is reported by Hughes to be $400K, but the price is dependent upon several factors, such as logistic support and quantity purchased. The HDP-4000 is designed to be a fully logistically supported system and the purchase price is subject to the quantity of support bought.

Number of Units in Field:

HDP-4000	-	None
HDP-2000	-	20
PT525	-	27

Warranty: The manufacturer has not formulated a warranty policy.

Consumables: There are three principal components in the HDP-4000 which one considers major cost consumable items in formulating a dollar cost per hour. They are as follows:

Consumable Item	Cost Per Item	Expected Replacement Time
Liquid Crystal Light Valve	\$18K	5000 Hours
Low Power CRTs	\$7K	30,000 Hours
Xenon Lamp	\$1.5K	1500 Hours

Based upon the above information obtained from the manufacturer an operating cost of approximately \$9 per hour has been calculated. (These figures are based on the manufacturer's production projections.)

Additional Information: The first fully supported HDP-4000 system was operational in 1982. Over the last several years a monochrome system has been developed and marketed for both commercial and military (Navy) users. The commercial version, the HDP-2000 and the military version, the PT525, have sold 25 and 27 units respectively.

At the present time a three channel version of the HDP-4000, the HDP-6000 is under development by the manufacturer. This new full-color Liquid Crystal Light Valve (LCLV) system is similar to the four-color system. The new liquid crystal light valve system (LCLV) will add a third CRT-LCLV to the optical system now employed in the two channel system. The third CRT-LCLV will be a blue channel. The combination of the three channels (red, green, and blue), will produce an additive spectrum full-color display.

Kalart-Victor Corporation
Hultenius Street
Plainville, Connecticut 06062

Contact: Joseph Costag, Sales Manager

Telephone: (203) 747-1663

Display Systems: Telebeam II and IIT

The Kalart Victor Corporation manufactures the Telebeam II and Telebeam IIT, a low cost commercial monochrome CRT large screen display projector. The units deliver low brightness and low resolution performance in a device employing, at standard TV 525 line rates, commercial construction standards.

The Telebeam II is self-contained in a single enclosure that includes the projection CRT, optics, and electronics. The projector utilizes a Schmidt optical system, which consists of a spherically concave first surface mirror and corrector plate that collects and reflects the light rays generated by the CRT. A summary of the Telebeam II characteristics is as follows:

Screen Size: 1.4m X 1.8m to 2.7m X 3.6m

Projection Technique: Front or Rear

Color: Monochrome only

Brightness: Calculated to be 5fl; as measured from the screen center with full white modulation, using a 12 foot wide beaded screen with a gain of 1.5.

Luminous Output: 350 Lumens

Contrast Ratio:

$$\text{Contrast Ratio} = B_D/B_A$$

50:1 at center of screen
25:1 at edges of screen

Update Time: One frame time

Resolution: 500 lines at center of image
350 lines at corners

Image Mechanism: Direct image

Display Technique: Raster scan

Drift: Less than 3.0%

Brightness Uniformity: 2:1 from center screen to edge

Aspect Ratio: 4:3

X-Radiation: Conforms to HEW Radiation Performance Standards 21CFR

Initial Cost: Telebeam II, $5.5K
Telebeam IIT, $5.95K

Number of Systems in Field: >10,000

Power Consumption: 200 watts at 117V, 60Hz

Consumables: The major high failure rate component requiring replacement is the projection CRT; cost is reported to be $400, replacement at 350 hours. The electronics are warranteed for 90 days. Operating cost is estimated to be $2/hour.

Litton Data Systems
8000 Woodley Avenue
Van Nuys, California 91406

Contact: Neil A. Obright, Program Manager, Advanced Systems

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Display System: Electronic Tactical Map

Litton Data Systems has developed a fully militarized light emitting diode (LED) display module which can be used to assemble flat panel displays ranging in size from several square inches to several square feet. Large screen displays of moderate cost have been fabricated using this component and are available upon special order. The LED screen display provides moderate brightness and moderate resolution display presentations.

The modules are flat, four edge-abuttable plug-in units with LEDs on the front surface and associated electronics, including refresh memory, mounted inside the case. These modules are available in single-color or three colors (red, green, and yellow, yellow obtained by mixing red and green) and with various resolutions, character size, and display capacities. Each module is 3.66 X 7.32 cm. and provides 2048 pixels arranged in a 32 X 64 line matrix. Using these modules, Litton Data Systems is presently developing three-color situation displays.

Characteristics of the Litton Light Emitting Diode Display are:

Display Technique: Light emitting diodes; infrared switching

Luminance: Full system, 1.8 to 2.5 lumens/watt

Resolution: 20 or 22 TV lines, multi-color; 33 TV lines in monochrome

Screen Size: 1.6" X 3.2" up to 6′ X 6′

Color: Red, green and amber

Monochrome: Red, green or yellow

Brightness: 100 foot lamberts

Contrast Ratio: 35:1

Update Time: 3 milliseconds

Scan Mode: Matrix addressed

Aspect Ratio: Depends on module configuration desired. (Module aspect ratio, 2:1.)

Brightness Uniformity: Within 25% over entire display

Module Size: Single display module size - 1.6" X 3.2"

Acquisition Cost: Electronic Tactical Map (28.8" by 22.4" display surface) is $250,000 in production quantities. (The individual 20 and 22 lines/inch modules are priced at $850/module; the 33 lines/inch at $1000 per module.)

Number of Units in Field: None

Consumables: In the Electronic Tactical Map (display surface - 28.8" by 22.4") each 33 lines/inch module contains approximately 5000 LEDS. Assuming that one LED failed every 1000 hours, the display which contains 108 modules would have a failure rate of one LED every 9.3 hours. If we assume that 50 LED failures per module would require a module replacement, a module would be replaced every 465 hours. The cost of a module is $850. The resultant cost per hour is less than $2 per hour.

The manufacturer warrants the module for 76,000 hours.

Additional Facts: Litton has not sold the Tactical Display Map to date but has delivered two Interactive Communication presentation panels (0.5m X 0.5m) to the Army. These units are presently being used in Germany. According to the manufacturer, the units have been in field use for two years without a failure.

Singer Company
Librascope Division
833 Sonora Avenue
Glendale, California 91201

Contact: Dr. Robert C. Tsai, Manager, Advanced Displays
T. B. Aitken, Manager, Display Programs

Telephone: (213) 244-6541

Display System: Multi-Color Liquid Crystal Display, Model SL-2448

The Librascope Division of Singer has developed a high data density multicolor laser liquid crystal large screen display system. This rear projection system delivers high brightness and high resolution to display screens as large as 3.7m by 3.7m. This was demonstrated at Singer/Librascope in January 1981. The update time of the system is in the order of 50 characters or symbols per second in the random plot mode (raster mode: frame update in ten seconds) and employs a laser as a writing instrument.

The large screen display (LSD) system makes use of two smectic liquid crystal light valves (SLCLV) which are thermally addressed by a single laser selectively. A four-color data display is produced; three-color graphic and alphanumeric on a fourth color background. A six-color system is planned. In the present system, the Nd:YAG laser beam is directed to address an assigned light valve channel by means of a proprietary optical channel selecting element. The laser writing system consists of the laser, a modulator which enables the formation of discrete data elements on the SLCLV, a two axis galvanometer deflection unit and a beam splitting optical package designed to multiplex the writing laser on each light valve. Either of the two light valves can be addressed selectively or simultaneously to create a color spectrum between the two prime colors determined by the color filters inserted in each light valve projection path.

Through the illumination optics, the two smectic liquid crystal light valves (SLCLV) are projected separately through a color filter to generate two colors (red and green) of different images on the display screen. The third color, yellow, is obtained by superimposing two identical images from both light valves. The fourth color, black, is produced by blocking off the projection light by the same image in both channels. Each light valve can be operated in either bright field mode (black image on a black

background) or dark field mode (color image on a black background). Using this technique a matrix of color combinations can be generated.

Screen Size: Up to 30 square meters (260 square feet)

Color: The system generates red, green, yellow and black by using selective filters. A variety of colors can be obtained by election of either the bright field mode or dark field mode.

Luminous Output: Quoted up to 2000 lumens per channel, white light.

Resolution: 2000 TV lines

Image Mechanism: Liquid Crystal Light Valve

Display Technique: Raster scan or random plot

Contrast Ratio: Up to 50:1

Display Accuracy: Distortion less than 0.1%

Display Data Capacity: 2048 X 2048 addressable points - random address, raster - 2048 lines

Update Time: 50 characters or symbols per second in random plot mode. Raster frame update in ten seconds.

Initial Cost: The manufacturer reports an initial cost of $500K (actual cost is dependent upon the number of units procured and specific application requirements).

Number of Units in Field: None

Warranty: The manufacturer has not formulated a warranty policy.

Consumables: There are four principal items in the Model SL-2448 which are considered "consumable items" used in the calculation of operating cost per hour. They are:

Consumable Item	Cost Per Item	Expected Replacement Time
Liquid Crystal Light Valve	$7K	26,000 Hours
Laser	$6K	43,000 Hours

(continued)

Consumable Item	Cost Per Item	Expected Replacement Time
Xenon Lamp	$700	1500 Hours
Laser Pumping Lamp	$100	400 Hours

The manufacturer has quoted an operating cost of approximately $7 per hour for the system. The reliability estimates assume operation of mature components. The costs of the liquid crystal appear to be based upon that obtained from moderate volume production runs and not based upon initial units or low volume conditions.

MTBF: 2600 hours for major components

MTTR: 25 minutes

Additional Information: Singer plans to develop and market a dual full-color projection display system. This new full-color system will consist of two separate channels; the present red and green, and a blue and orange. An additive combination of the red, green, and blue will produce a full-color spectrum. The additional orange channel will be an extra capability for the display of attention information.

The newer Singer projection system will have separate outputs optics. Each dual channel projector will image its display on a display screen with the image from the other dual channel projector.

Videpro International Products Limited
P. F. Gambuti Associates
590 Alps Road
Wayne, New Jersey 07470

Contact: Patrick F. Gambuti, President

Telephone: (201) 696-8832

Display System: Hi-Beam Video Projection System

Gambuti Associates of Wayne, New Jersey markets the Hi-Beam Video Projection System manufactured by Videpro International Products Limited, Dublin, Ireland. This tri-tube CRT large screen color projector is a low-cost, commercial, off-the-shelf item. The system delivers low brightness television resolution performance at standard PAL and NTSC rates.

A portable self-contained unit of CRTs, projection optics and electronics is packaged in a 28" x 24" x 9.75" housing. This direct projection CRT system utilizes an electron beam to produce a display on the phosphor of the individual tubes. The face of the CRTs is coupled to refractive lens by a liquid-cooling CRT face-plate module; the liquid has a refractive index equal to the face-plates.

A summary of the Hi-Beam characteristics is given below.

Screen Size: 4.5' x 6' to 10.5' x 14'

Projection Technique: Front or Rear

Color: Full-color

Brightness: Calculated to be 7fl as measured from the screen center with full white modulation using a 7.5' x 10' screen with a gain of 1.5.

Luminous Output: 350 Lumens

Contrast Ratio:

Contrast Ratio = $^{B}D/^{B}A$

40:1, Center Screen

Image Mechanism: Direct Image

Display Technique: Raster scan

Update Time: One frame

Resolution: 525 lines at center

Drift: Less than 3.0%

Aspect Ratio: 4:3

X-Radiation: Conforms to HEW Radiation Performance Standards 21CFR

Initial Cost: Hi-Beam - $16K (includes liquid cooling)

Number of Systems in Field: >100

Power Consumption: 250 watts at 116V, 60Hz

Consumables: The major components requiring replacement are the CRTs. The cost of each CRT is $125, less cooling module, or $475 including cooling module. The CRTs are warranteed for 250 hours. Operating cost per hour is estimated to be $0.50/hr or $2.00/hr depending upon whether the cooling module is replaced with CRT replacement.

APPENDIX B

TABULAR LISTING OF LARGE SCREEN DISPLAY CHARACTERISTICS

Manufacturer:	Aydin Controls
Model:	8063
Projection Technique:	Direct CRT Projection
Color Capability:	Monochrome
Luminous Flux (Lumens):	300
Contrast Ratio:	5:1
Resolution:	1000 Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	<15 seconds
Update Time:	33 mseconds
Maximum Display Size:	6′ by 6′
Throw Distance:	14′
Display Aspect Ratio:	3:4
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	115VAC $\pm$ 10% 60 Hz, 300 Watts
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	20 MHz
Consumables:	CRT
Operating Cost/Hour:	$2
Initial Cost (July 1983):	$45,000

Manufacturer:	Aydin Controls
Model:	8063-C
Projection Technique:	Direct CRT Projection
Color Capability:	Four-Color
Luminous Flux (Lumens):	300
Contrast Ratio:	5:1
Resolution:	1000 Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	<15 seconds
Update Time:	50 useconds
Maximum Display Size:	6′ by 6′
Throw Distance:	14′
Display Aspect Ratio:	3:4
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	115VAC ± 10% 60 Hz, 300 Watts
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	20 MHz
Consumables:	CRTs
Operating Cost/Hour:	$4
Initial Cost (July 1983):	$85,000

Manufacturer:	Aydin Controls
Model:	8063-A
Projection Technique:	Direct CRT Projection
Color Capability:	Full-Color
Luminous Flux (Lumens):	300
Contrast Ratio:	5:1
Resolution:	1000 Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	<15 seconds
Update Time:	50 useconds
Maximum Display Size:	6′ by 6′
Throw Distance:	14′
Display Aspect Ratio:	3:4
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	115VAC ± 10% 60 Hz, 300 Watts
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	20 MHz
Consumables:	CRTs
Operating Cost/Hour:	$6
Initial Cost (July 1983):	$120,000

Manufacturer:	Electronic Systems Products
Model:	Aquastar IIIB
Projection Technique:	Direct CRT Projection
Color Capability:	Full-Color
Luminous Flux (Lumens):	400
Contrast Ratio:	30:1
Resolution:	600 Lines RGB - 300 NTSC Video
Display Technique:	Raster Scan
Time from Standby:	Instantaneous
Update Time:	30 mseconds
Maximum Display Size:	19′ by 25′
Throw Distance:	1.5 by Width
Display Aspect Ratio:	3:4
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front, Rear
Power Requirements:	110VAC, 60 Hz, 400 Watts
TV Standards:	525, 626 Scan Lines
Video Amplifier Bandwidth:	NTSC 2.8 MHz, RGB 15 MHz
Consumables:	CRTs
Operating Cost/Hour:	$1 to $2
Initial Cost (July 1983):	$10,000

Manufacturer:	Ford Aerospace
Model:	ATP-1000
Projection Technique:	Direct CRT Projection
Color Capability:	Monochrome
Luminous Flux (Lumens):	280
Contrast Ratio:	15:1
Resolution:	1000 Lines
Display Technique:	Raster Scan
Time from Standby:	Immediate (after one hour warm-up)
Update Time:	33 mseconds
Maximum Display Size:	5′ by 5′
Throw Distance:	10′
Display Aspect Ratio:	1:1 and 4:3
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front to Rear
Power Requirements:	115VAC, 400 Hz, 3 KW
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	40 MHz
Consumables:	CRTs
Operating Cost/Hour:	$3
Initial Cost (July 1983):	$150,000

Manufacturer:	Ford Aerospace
Model:	ATP-3000
Projection Technique:	Direct CRT Projection
Color Capability:	Four-Color
Luminous Flux (Lumens):	300
Contrast Ratio:	15:1
Resolution:	1000 Lines
Display Technique:	Raster Scan
Time from Standby:	Immediate (after one hour warm-up)
Update Time:	33 mseconds
Maximum Display Size:	15′ Diagonal
Throw Distance:	2 by Width
Display Aspect Ratio:	1:1 or 4:3
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	115VAC, 60 Hz, 5 KW
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	40 MHz
Consumables:	CRTs
Operating Cost/Hour:	$10
Initial Cost (July 1983):	$500,000

Manufacturer:	Ford Aerospace
Model:	ATP-6000
Projection Technique:	Direct CRT Projection
Color Capability:	Full-Color
Luminous Flux (Lumens):	1200
Contrast Ratio:	15:1
Resolution:	1000 Lines
Display Technique:	Raster Scan
Time from Standby:	Immediate (after one hour warm-up)
Update Time:	33 mseconds
Maximum Display Size:	15′ Diagonal
Throw Distance:	2 by Width
Display Aspect Ratio:	1:1 and 4:3
Brightness Uniformity:	50% Variation Across Screen
Projection Direction:	Front or Rear
Power Requirements:	115VAC, 60 Hz, 11.5K
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	40 MHz
Consumables:	CRTs
Operating Cost/Hour:	$90
Initial Cost (July 1983):	$1,000,000

Manufacturer:	General Atronics/Sodern
Model:	Titus SVS12
Projection Technique:	Solid-State Light Valve
Color Capability:	Full-Color
Luminous Flux (Lumens):	1500 - 1900
Contrast Ratio:	100:1
Resolution:	525, 625 TV Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	Two minutes
Update Time:	30 mseconds
Maximum Display Size:	Dependent on Brightness and Lens
Throw Distance:	Variable
Display Aspect Ratio:	1:1, 3:4
Brightness Uniformity:	1.5:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	120/240V, 50/60Hz, 8KW
TV Standards:	525, 625 Scan Lines
Video Amplifier Bandwidth:	20 MHz
Consumables:	Light Valve, Xenon Lamp
Operating Cost/Hour:	\$6 to \$10
Initial Cost (July 1983):	\$250,000

Manufacturer:	General Dynamics
Model:	303B
Projection Technique:	Direct CRT Projection
Color Capability:	Monochrome
Luminous Flux (Lumens):	560
Contrast Ratio:	80:1
Resolution:	1000 Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	<90 seconds (after 30 minute warm-up)
Update Time:	30 mseconds
Maximum Display Size:	15′ by 15′
Throw Distance:	1.4 by Diagonal
Display Aspect Ratio:	1:1
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	110VAC, 60 Hz, 4 KW
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	40 MHz
Consumables:	CRTs
Operating Cost/Hour:	$2
Initial Cost (July 1983):	$60,000

Manufacturer:	General Dynamics
Model:	303C
Projection Technique:	Direct CRT Projection
Color Capability:	Four-Color
Luminous Flux (Lumens):	1000
Contrast Ratio:	80:1
Resolution:	1000 Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	<90 seconds (after 30 minute warm-up)
Update Time:	30 mseconds
Maximum Display Size:	15′ by 15′
Throw Distance:	1.4 by Diagonal
Display Aspect Ratio:	1:1
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Front, Rear
Power Requirements:	110VAC, 60 Hz, 4 Kw
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	40 MHz
Consumables:	CRTs
Operating Cost/Hour:	$4
Initial Cost (July 1983):	$120,000

Manufacturer:	General Dynamics
Model:	303F
Projection Technique:	Direct CRT Projection
Color Capability:	Full-Color
Luminous Flux (Lumens):	1200
Contrast Ratio:	80:1
Resolution:	1000 Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	<90 seconds (after 30 minute warm-up)
Update Time:	30 mseconds
Maximum Display Size:	15′ by 15′
Throw Distance:	1.4 by Diagonal
Display Aspect Ratio:	1:1
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Front, Rear
Power Requirements:	110VAC, 60 Hz, 4 Kw
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	40 MHz
Consumables:	CRTs
Operating Cost/Hour:	$4
Initial Cost (July 1983):	$250,000

Manufacturer:	General Electric Company
Model:	PJ7000
Projection Technique:	Oil Film Light Valve
Color Capability:	Monochrome
Luminous Flux (Lumens):	750
Contrast Ratio:	75:1
Resolution:	1000 Lines
Display Technique:	Raster Scan
Time from Standby:	One minute
Update Time:	30 mseconds
Maximum Display Size:	15′ by 20′
Throw Distance:	3 by Width
Display Aspect Ratio:	4:3
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	120/220V at 1KVA
TV Standards:	525 - 1029 Line Scan
Video Amplifier Bandwidth:	20 MHz
Consumables:	Light Valve Assembly, Xenon Lamp
Operating Cost/Hour:	$6
Initial Cost (July 1983):	$55,500

Manufacturer:	General Electric Company
Model:	PJ5050
Projection Technique:	Oil Film Light Valve
Color Capability:	Four-Color
Luminous Flux (Lumens):	550
Contrast Ratio:	75:1
Resolution:	1000 Lines
Display Technique:	Raster Scan
Time from Standby:	One minute
Update Time:	30 mseconds
Maximum Display Size:	15′ by 20′
Throw Distance:	3 by Width
Display Aspect Ratio:	4:3
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	120VAC at 1KVA
TV Standards:	525 - 1029 Line Scan
Video Amplifier Bandwidth:	20 MHz
Consumables:	Light Valve Assembly, Xenon Lamp
Operating Cost/Hour:	$4
Initial Cost (July 1983):	$72,500

Manufacturer:	General Electric Company
Model:	PJ5155
Projection Technique:	Oil Film Light Valve
Color Capability:	Full-Color
Luminous Flux (Lumens):	1000
Contrast Ratio:	75:1 Minimum
Resolution:	1000 Lines
Display Technique:	Raster Scan
Time from Standby:	One minute
Update Time:	30 mseconds
Maximum Display Size:	15′ by 20′
Throw Distance:	3 by Width
Display Aspect Ratio:	3:4
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front, Rear
Power Requirements:	120VAC, 1KVA
TV Standards:	525 - 1029 Scan Lines
Video Amplifier Bandwidth:	20 MHz
Consumables:	Light Valve Assembly, Xenon Lamp
Operating Cost/Hour:	$7
Initial Cost (July 1983):	$82,000

Manufacturer:	Gretag/Eidophor
Model:	Eidophor 5170
Projection Technique:	Oil Film Light Valve
Color Capability:	Full-Color
Luminous Flux (Lumens):	3600
Contrast Ratio:	100:1
Resolution:	800 TV Lines
Display Technique:	Raster Scan
Time from Standby:	10 minutes
Update Time:	33 mseconds
Maximum Display Size:	30′ by 40′
Throw Distance:	150′
Display Aspect Ratio:	3:4
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	3.0 KVA and 5.6 KVA
TV Standards:	525, 625, 1029 Scan Lines
Video Amplifier Bandwidth:	30 MHz
Consumables:	Xenon Lamp
Operating Cost/Hour:	$22
Initial Cost (July 1983):	$450,000

Manufacturer:	Gretag/Eidophor
Model:	Eidophor 5171
Projection Technique:	Oil Film Light Valve
Color Capability:	Full-Color
Luminous Flux (Lumens):	7000
Contrast Ratio:	100:1
Resolution:	800 TV Lines
Display Technique:	Raster Scan
Time from Standby:	10 minutes
Update Time:	33 mseconds
Maximum Display Size:	39′ by 53′
Throw Distance:	150′
Display Aspect Ratio:	3:4
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	3.0 KVA and 5.6 KVA
TV Standards:	525, 625, 1029 Scan Lines
Video Amplifier Bandwidth:	20 MHz
Consumables:	Xenon Lamp
Operating Cost/Hour:	$46
Initial Cost (July 1983):	$505,000

Manufacturer:	Gretag/Eidophor
Model:	5180
Projection Technique:	Oil Film Light Valve
Color Capability:	Black and White
Luminous Flux (Lumens):	4000
Contrast Ratio:	100:1
Resolution:	800 TV Lines
Display Technique:	Raster Scan
Time from Standby:	10 minutes
Update Time:	33 mseconds
Maximum Display Size:	30′ by 40′
Throw Distance:	150′
Display Aspect Ratio:	3:4
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	3.0 KVA and 5.6 KVA
TV Standards:	525, 625, 1029 Scan Lines
Video Amplifier Bandwidth:	20 MHz
Consumables:	Xenon Lamp
Operating Cost/Hour:	$7
Initial Cost (July 1983):	$190,000

Manufacturer:	Hughes Aircraft Company
Model:	HDP-4000
Projection Technique:	Liquid Crystal Light Valve
Color Capability:	Four-Color
Luminous Flux (Lumens):	500
Contrast Ratio:	20:1 (Yellow)
Resolution:	1024 Lines in 1075 Line Raster
Display Technique:	Raster Scan
Time from Standby:	15 - 30 minutes
Update Time:	33 mseconds
Maximum Display Size:	12′ by 12′
Throw Distance:	(1.3 - 2.0) by Width
Display Aspect Ratio:	1:1
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	220VAC, 47 to 63 Hz at 4KW
TV Standards:	NA
Video Amplifier Bandwidth:	20 MHz
Consumables:	CRT, Xenon Lamp
Operating Cost/Hour:	$9
Initial Cost (July 1983):	$400,000

Manufacturer:	Kalart-Victor Corporation
Model:	Telebeam II
Projection Technique:	Direct CRT Projection - Schmidt Optics
Color Capability:	Monochrome Only
Luminous Flux (Lumens):	350
Contrast Ratio:	50:1
Resolution:	525 or 1029 Lines, Switchable
Display Technique:	Raster Scan
Time from Standby:	Immediate
Update Time:	30 mseconds
Maximum Display Size:	15′ by 20′
Throw Distance:	25′
Display Aspect Ratio:	4:3
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front or Rear
Power Requirements:	117VAC, 60 Hz
TV Standards:	NA
Video Amplifier Bandwidth:	12 MHz
Consumables:	CRT
Operating Cost/Hour:	$2
Cost (July 1983):	$6000

Manufacturer:	Litton Data Systems
Model:	Tactical Display Map
Projection Technique:	Light Emitting Diode Modules
Color Capability:	Three-Colors or One-Color
Luminous Flux (Lumens):	225
Contrast Ratio:	3.5:1
Resolution:	22 Pixels/Inch
Display Technique:	Matrix Addressed
Time from Standby:	<10 seconds
Update Time:	3 mseconds
Maximum Display Size:	6′ by 6′
Throw Distance:	NA
Display Aspect Ratio:	2:1
Brightness Uniformity:	Within 25%, Entire Area
Projection Direction:	Front
Power Requirements:	+5VDC, 15.5VCD, 110VAC, 77 Amps
TV Standards:	NA
Video Amplifier Bandwidth:	NA
Consumables:	LEDs
Operating Cost/Hour:	<$2
Initial Cost (July 1983):	$250,000

Manufacturer:	Singer Company
Model:	SL-2448
Projection Technique:	Liquid Crystal Light Valve
Color Capability:	Four-Color
Luminous Flux (Lumens):	880 - 1000
Contrast Ratio:	50:1
Resolution:	2000 Lines
Display Technique:	Raster Scan or Random Plot
Time from Standby:	10 minutes
Update Time:	50 Characters/Second
Maximum Display Size:	9′ by 12′
Throw Distance:	12′
Display Aspect Ratio:	3:4
Brightness Uniformity:	<2:1 Center to Edge
Projection Direction:	Rear
Power Requirements:	120/240V, 50/60 Hz, 2.5KW
TV Standards:	NA
Video Amplifier Bandwidth:	20 MHz
Consumables:	Liquid Crystal Light Valve, Laser, Xenon Lamp
Operating Cost/Hour:	$7
Initial Cost (July 1983):	$300,000

AD-A144 222 LARGE SCREEN DISPLAY TECHNOLOGY SURVEY(U) MITRE CORP BEDFORD MA R M CARBONE JUL 84 MTR-8907 ESD-TR-84-165 F19628-82-C-0001

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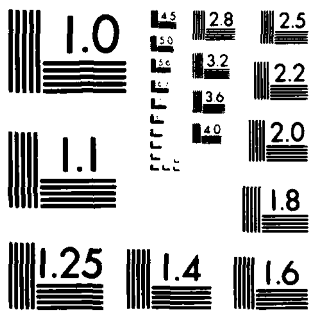

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

Manufacturer:	Videpro International Products Limited
Model:	Hi-Beam
Projection Technique:	Direct CRT Projection
Color Capability:	Full-Color
Luminous Flux (Lumens):	350
Contrast Ratio:	40:1
Resolution:	600 Lines RGB, 330 NTSC Video
Display Technique:	Raster Scan
Time from Standby:	Immediate
Update Time:	30 mseconds
Maximum Display Size:	10.5′ by 15′
Throw Distance:	1.5′ by Width
Display Aspect Ratio:	3:4
Brightness Uniformity:	2:1 Center to Edge
Projection Direction:	Front to Rear
Power Requirements:	300 - 400 Watts
TV Standards:	525 Scan Lines
Video Amplifier Bandwidth:	NTSC 2.8 MHz, RGB 15 MHz
Consumables:	CRT
Operating Cost/Hour:	$1 to $2
Initial Cost (July 1983):	$16,000

APPENDIX C

PROJECTION SCREENS

In presenting data or information through the utilization of a projection technique, a projection screen is employed to display the images. Front and rear projection techniques are used in large screen display systems. The differences in the two projection methods is that in front projection the projector is placed in the audience area and the viewing screen is illuminated from the front; in rear projection the projector is located behind the viewing screen (not seen by the audience) and the screen is illuminated from the rear side. In both front and rear projection the light must be diffused by reflection or refraction to obtain the desired view angle. Projection screens are generally customized for a particular room. Several projector manufacturers have developed computer programs for modeling purposes. Table IV depicts the characteristics of several standard front and rear projection screens.

Characteristics of projection screens that affect the appearance of the displayed image are reflectance, transmittance and resolving power. Reflectance and transmittance refer to the percentage of incident light that is either reflected or transmitted by the screen. In front projection, to provide optimum brightness, the screen should exhibit high reflectance and low transmittance. In rear projection the opposite is true. Resolving power of the screen is a measure of image clarity; how well the alphanumerics or graphics are viewed.

The major characteristic of a projection screen is the manner in which it diffuses an incident light beam. This property of the screen is referred to as "gain" and is the ratio of brightness to incident illumination. A screen that diffuses light equally in all directions provides a gain of 1.0 (unity gain).

The characteristics of a projection viewing screen are usually defined based upon the diffusion properties, the available luminance, the audience dispersion, and the ambient lighting in the audience area. The first step in selecting a screen is to determine the projection technique, front or rear. Rear projection provides contrast enhancement. The use of this technique requires the allocation of space behind the screen for the projector. Front projection provides reduced contrast ratios. Rear projection screens should be considered if possible.

TABLE IV

PROJECTION SCREEN CHARACTERISTICS

Rear Projection Screens

Physical Features	Maximum Gain	Percent Transmittance	Percent Reflection	Resolving Power Lines/MM	Maximum Viewing Angle Degrees Horizontal
A. Flexible White Plastic	3.05	72	24	16	53
B. Clear Plastic With Gray Diffuser	1.56	45	11	29	62
C. Flexible Gray Plastic	1.98	53	12	18	60
D. Freen Mark XII	N/A	(High)*	(Low)*	(High)*	90*
E. Freen Mark III A	N/A	(High)**	(Low)**	(High)**	120*

* Author Observations
** Reported

Front Projection Screens

Physical Features	Maximum Gain	Percent Transmittance	Percent Reflection	Resolving Power Lines/MM	Maximum Viewing Angle Degrees Horizontal
A. White Semi-Gloss	1.7	—	83	29	—
B. Aluminized Plastic	3.6	—	61	20	44
C. Beaded Glass	2.5	—	75	4	43
D. Aluminized Lenticular	1.8	—	---	20	88

Two advantages rear projection screens have over front projection screens are, first, special rear projection screens have been manufactured with high gain (greater than 1.0) at no loss of view angle. Screens such as these specially designed rear projection screens improve the apparent brightness of any rear projection without sacrificing viewing area. Second, the combination of rear projection and a high gain screen permits a much higher ambient light level in the audience area; since rear projection screens have a low front surface reflectivity, they reflect only a small portion of the ambient light back into the viewing area.

APPENDIX D

COMPARISON OF FREEN MARK XII[1] WITH UNITY GAIN SCREEN

Recently, as part of a demonstration of the General Electric PJ5050 Large Screen Projection System at MITRE-Washington, brightness measurements were made; a 4′ by 6′ Freen Mark XII Rear Projection Screen was compared with a standard on a Unity Gain Screen leased from the Executive Communications Corporation.

A Spectra Photometer Control Unit (calibrated for this test) borrowed from the John Hopkins University Applied Physics Laboratory was used to collect brightness data. A white background display was projected onto the rear of both screens. The projector to screen distance was 21 feet.

The following measurements were made on the audience side of the screen. The observed luminance was measured in foot-lamberts.

Location of Photometer	Freen Screen (Foot-Lamberts)	Unity Gain Screen (Foot-Lamberts)
Center of Display	25	16
22 1/2° Off-Center	26	11
45° Off-Center	27	5
60° Off-Center	10	No Reading

Gain is the increase in luminance compared to ambient white light. Based on the data shown below, the observed luminance was greater for the Freen Screen than for the Unity Gain Screen. If the photometer measurements taken from the front side of both screens are divided by the measurement of illumination incident on the rear of the screens, the following gains are produced:

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[1] Now manufactured by Phoenix Communications of Baltimore, MD under the product name "Optixx Mark XX".

IA-64,905

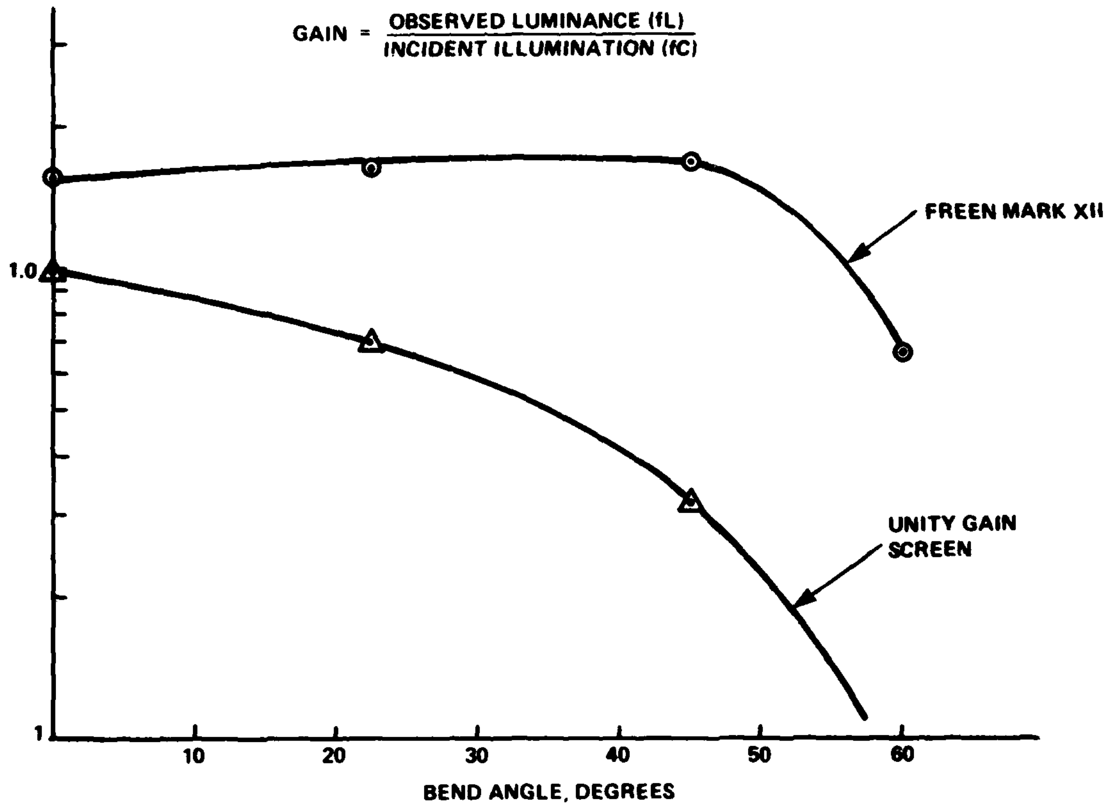

Figure 12. PLOT OF GAIN VS. BEND ANGLE (FREEN AND UNITY GAIN SCREENS)

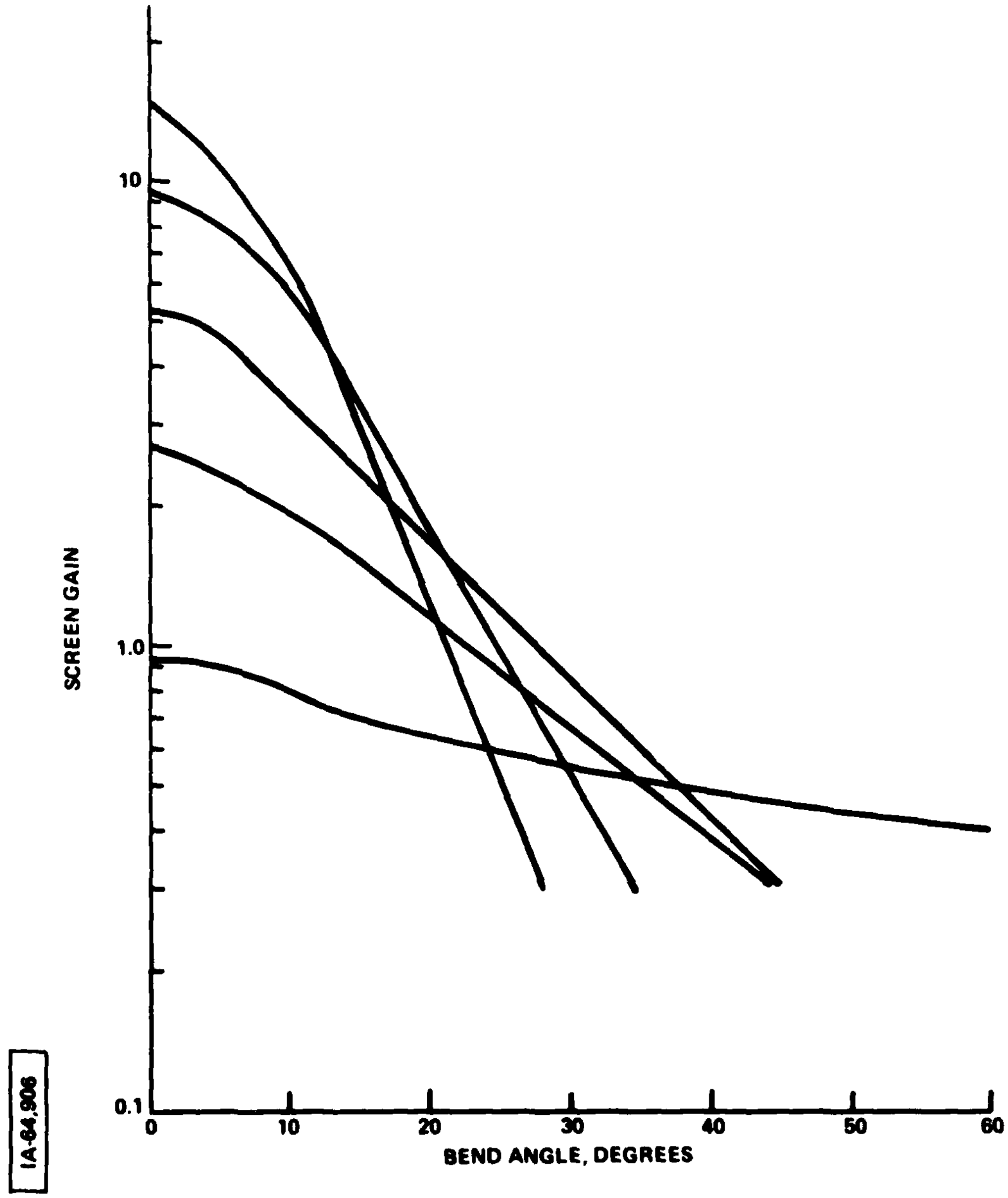

Figure 13. DIFFUSION CHARACTERISTIC OF TYPICAL REAR PROJECTION SCREENS

IA-64,907

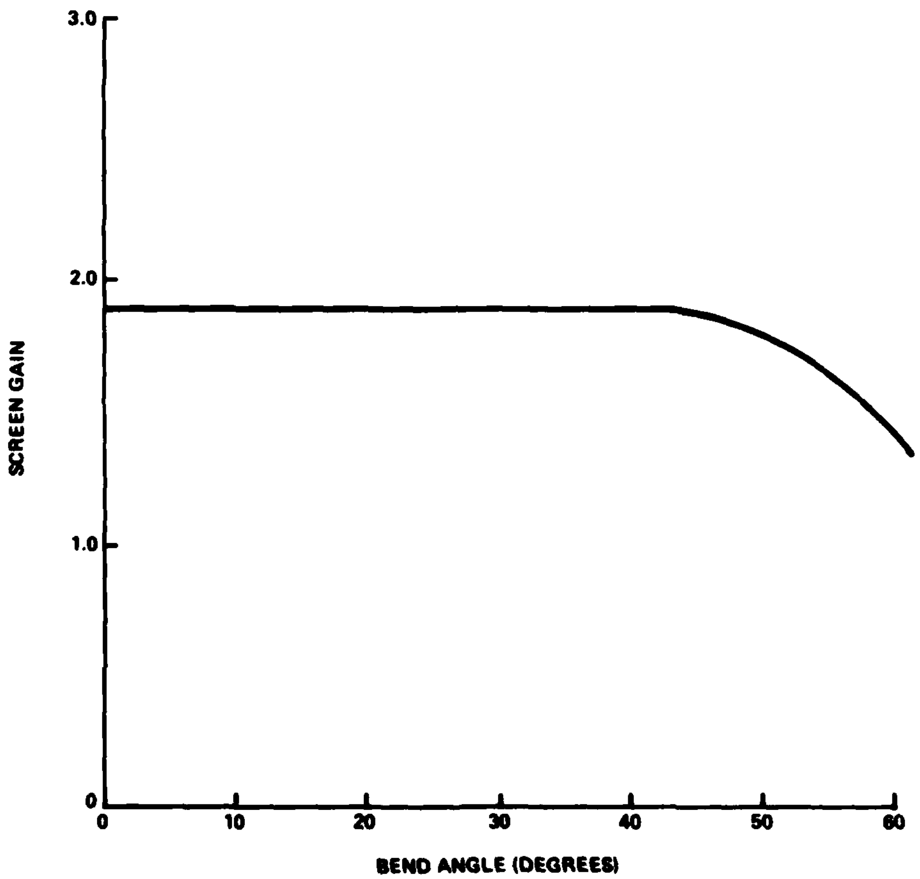

Figure 14. FULLY LENTICULAR SCREEN

Freen	Calculation	Gain
At Center Screen	$\frac{25}{16}$	1.563
22^{o} Off-Center	$\frac{26}{16}$	1.625
45^{o} Off-Center	$\frac{27}{16}$	1.688
60^{o}	$\frac{10}{16}$	0.625

Unity Gain	Calculation	Gain
At Center Screen	$\frac{16}{16}$	1.0
22^{o} Off-Center	$\frac{11}{16}$	0.688
45^{o} Off-Center	$\frac{5}{16}$	0.313

A plot of this rear screen data translated to gain as a function of bend angle is shown in Figure 12. Figure 13 shows several other rear projection screens plotted to the same parameters. A fully lenticular screen theoretical plot is shown in Figure 14. Several important conclusions can be drawn from the presented data. Figure 13 indicates that screens with a gain above one have small bend angles and that screens with low gain have large bend angles. Note in Figure 12 that the Freen Mark XII screen's gain is practically constant to 45^{o} and that this screen has a large "figure of merit".[2] By comparison, the data from the unity gain screen shows a dramatic decrease in gain with increase in bend angle and that its "figure of merit" is small.

The current cost for a Freen Rear Projection screen is $125 per square foot. A standard unity gain screen price varies from

[2] "The bend-angle that can be attained before the gain of the screen has fallen to one half of its peak value constitutes a measure of quality or "figure of merit".

approximately $5 to $20 per square foot depending on the type of construction and gain characteristics.

The data (Figure 12) indicates that the Freen rear projection screen has excellent horizontal and vertical viewing angles and good gain. This screen comes closest to providing a customized luminance distribution pattern.

GLOSSARY OF TERMS

Ambient Lighting - Lighting conditions in the environment or surroundings. Normally, ambient lighting ranges from levels of one to two foot-candles for dimly lit rooms to more than 50 foot-candles for well lit areas. When considering brightness requirements for displays, levels not less than, and generally twice as great as, the ambient illumination are desirable.

Aspect Ratio - The ratio of display screen width to height; in commercial television the value is 4 to 3. The term aspect ratio is also applied to the ratio of the width of displayed characters and symbols to their height.

Birefringence - The refraction of light in two slightly different directions to form two light rays.

Catoptic - Relating to a mirror or reflected light.

CRT - Cathode Ray Tube

Dioptic - Relating to refraction of light.

fl - Foot-Lamberts

GEP - Gas-Electron Phosphor

LED - Light Emitting Diode

LCLV - Liquid Crystal Light Valve

LSWD - Large Screen Wall Display

Lumen - The basic unit of measurement of luminous flux. It is equivalent to the rate of flow of luminous energy produced by a point source with a luminous intensity of one candela within a unit solid angle (steradian) out from the candle.

Luminance - A physical quantity which describes the luminous energy which is emitted by an area of light emitting surface. It may be defined in terms of luminous intensity per unit area of the light emitting surface (it can be expressed in candelas per square meter).

Faraday Effect - The effect associated to a crystal when subjected to a magnetic field which causes optical activity within the crystal. When plane-polarized light is sent through a crystal

in a direction parallel to the applied magnetic field the plane of vibration is rotated.

Foot-Candle - A foot-candle is a measure of light falling on a surface. It is a unit of illumination which is that illumination on a surface which is everywhere one foot from a point light source of one candela. It is equivalent to one lumen per square foot.

Foot-Lambert - A unit of brightness (or luminance) which is equivalent to a surface which is radiating or reflecting one lumen per square foot. A foot-lambert is a measure of light coming off a surface, and is the brightness of a "perfectly" diffusing surface - generally magnesium carbonate - reflecting the illumination of one foot-candle.

MTBF - Mean-Time-Between-Failures

MTTR - Mean-Time-To-Repair

Nd:YAG - Noedymium: Yttrium Aluminum Garnet

Nematic - A term used to describe one of the states of certain liquid crystals which are used in liquid crystal light valve displays. It is defined as "relating to, existing in, or being a mesomorphic state (intermediate between liquid and crystal) which is the first state formed on cooling from a liquid melt, and in which the orientation of the molecules or atoms is in parallel lines but not in layers."

NTSC - National Television System Committee

Schlieren Optics - An optical system which uses a vertically slotted mirror with slots as wide as the mirror strips. The system allows part of the incident light to pass through and reflects the remaining light.

Schmidt Optics - An optical system or technique which utilizes a spherical mirror rather than a conventional lens. Because of this, it allows the use of a lower numeric aperture lens, resulting in a high brightness system.

Smectic - A term used to describe one of the states of certain liquid crystals when they are used in laser driven liquid crystal light valve displays. It is defined as "relating to, existing in, or being a mesomorphic state (intermediate between

liquid and crystal) which is formed after the nematic state on cooling from a liquid melt, and in which the orientation of the molecules or atoms is in parallel planes or layers".

Smectic Liquid Crystal Light Valve - A liquid crystal light valve in which the liquid crystals exist in a smectic state at room temperature, but undergo a smectic-nematic transition when thermally addressed (locally heated) by a single laser beam. When the liquid crystal molecules are heated by the laser beam they transform to a nematic state and possess a randomly oriented order. If cooling is slow the molecules realign themselves and produce a clear state. If, however, cooling is rapid,the molecules will not be able to realign themselves in time; they will exhibit a random orientation and show up as a dark image when projected onto a screen through suitable projection optics.

Twisted-Nematic Liquid Crystal Displays - A liquid crystal display in which the nematic liquid is contained between two sheets of glass which have been surface-treated so that the nematic molecules (thread-like) near the surfaces align in the treated direction. The treated directions on the two glass sheets are arranged to form a right angle. Molecules near the glass surfaces align themselves in the related directions, but those in the middle (in the nematic liquid) realign to form a smooth changing quarter helix from one glass surface to the other. Optical properties of this helix are such that polarized light transmitted through it is rotated 90°.

When polarizers, rotated 90° from each other, are placed on the surfaces, light entering one surface will be transmitted through the other. This is the "ON" or "PRINT" condition of the display. If an external electric field is applied between the surfaces of glass, it causes the molecules in the nematic liquid to align perpendicularly to the surface. This breaks the helix and cancels the optical rotation effect. Light now entering one surface will be reflected by the other. This is the "OFF" or blank condition of the display.

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